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Inter-annual variation and long-term trends in proportions of resident individuals in partially migratory birds

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Summary

1. Partial migration – a part of a population migrates and another part stays resident year-round on the breeding site – is probably the most common type of migration in the animal kingdom, yet it has only lately garnered more attention. Theoretical studies indicate that in partially migratory populations the proportion of resident individuals (PoR) should increase in high latitudes in response to the warming climate, but empirical evidence exists for few species.

2. We provide the first comprehensive overview of the environmental factors affecting PoR and the long-term trends in PoR by studying 27 common partially migratory bird species in Finland.

3. The annual PoR values were calculated by dividing the winter bird abundances by the preceding breeding abundances. First, we analysed whether early-winter temperature, winter temperature year before or the

abundance of tree seeds just before overwintering, explain the inter-annual variation in PoR. Second, we analysed the trends in PoR between 1987 and 2011.

4. Early-winter temperature explained the inter-annual variation in PoR in the waterbirds (waterfowl and gulls), most likely because the temperature affects the ice conditions and thereby the feeding opportunities for the waterbirds. In terrestrial species, the abundance of seeds was the best explanatory variable. Previous winter's temperature did not explain PoR in any species, thus we conclude that variation in food availability caused the inter-annual variation in PoR. During the study period PoR increased in waterbirds but did not change in terrestrial birds.

5. Partially migratory species living in physically contrasting habitats can differ in their annual and long-term population-level behavioural responses to warming climate, possibly because warm winter temperatures reduce ice cover and improve the feeding possibilities of waterbirds but do not directly regulate the food availability for terrestrial birds.

Key-words animal movement, bird feeding, climate change, density-dependent strategy, fluctuating food availability, non-breeding habitat quality, range shift, wintering area

Introduction

Many species migrate annually between breeding and wintering areas in response to seasonal fluctuation in temperature and food availability (Alerstam 1990). Partial migration is a strategy where a part of a population migrates away from the breeding area (hereafter migrants), whereas the other part lives on the same area year-round (hereafter residents, Terrill & Able 1988). Partial migration emerges in a population when the individuals

confront contradictory selection pressures concerning migration: a part of a population achieves higher fitness by migrating whereas the other part achieves higher fitness by being resident (Kaitala, Kaitala & Lundberg 1993). The fitness consequences of overwintering in a certain place must be regulated by density dependence for partial migration to emerge because otherwise it would simply be most beneficial for all individuals to overwinter in the same area, *i.e.* either to migrate or to stay resident (Taylor & Norris 2007). Genetic studies indicate that the potential for changes in migration patterns is well preserved in populations (Pulido 2011) and a rapid change from a migratory to sedentary population can occur when selection pressures change (Berthold, Mohr & Querner 1990).

The inter-annual variation in food availability affects the migration behaviour of some partially migratory species (Fox *et al.* 2009; Lindén *et al.* 2011). In the boreal zone, the seeds of several tree species are important but fluctuating food resource for wintering animals. The inter-annual variation in seed crops causes variation in the wintering numbers of many seed- and berry-eating (hereafter frugivorous) birds (Haila, Tiainen & Vepsäläinen 1986).

One of the most important environmental variables affecting migration strategies is temperature, as demonstrated by the increase of the proportion of migratory bird species towards the poles (Newton & Dale 1996). In high latitudes or altitudes, wintering on or near the breeding site is risky because cold winters increase the energy expenditure of individuals and even can cause mortality (Robinson, Baillie & Crick 2007). On the other hand, wintering in the breeding area has many beneficial effects, like avoiding risky migration (Sillett & Holmes 2002), being able to optimize breeding phenology according to progression of spring (Love *et al.* 2010) and being among the first ones to occupy a breeding territory (Kokko 2011) .

Climate change has elevated global temperatures over the last 40 years with the most pronounced warming at higher northern latitudes during winters (IPCC 2013). An increase in winter temperature has the largest impact on the environmental conditions in regions where the mean winter temperature is near the zero °C isotherm, as in Finland. In these regions, even a small change in the temperature affects the occurrence and amount of ice and snow (Luomaranta *et al.* 2014), which influence the feeding opportunities of both terrestrial and aquatic species.

Climate warming has already shifted the breeding and wintering ranges of migratory and resident animals towards poles (*e.g.* Parmesan 2006; Brommer, Lehikoinen & Valkama 2012). The migration distances have become shorter in some species indicating a possible gradual change towards residency (Visser *et al.* 2009). In partially migratory populations, the proportion of individuals staying resident is expected to rise as the increasing winter temperatures improve food availability and survival of resident individuals (Berthold 2001, Griswold, Taylor & Norris 2011).

To our knowledge, few studies have focused on changes in proportions of residents in partially migratory species and whether the climate warming has contributed to these changes. The warming climate has increased the proportion of residents (hereafter PoR) in common blackbirds *Turdus merula* in the Netherlands (Vliet, Musters & Keurs 2009), but not in blue tits *Cyanistes caeruleus* in Sweden (Nilsson *et al.* 2006). PoR has increased also among great crested grebes *Podiceps cristatus* in the Netherlands (Adriaensen, Ulenaers & Dhondt 1993) and elks *Cervus elaphus canadensis* in North America (Hebblewhite & Merrill 2011). However, these responses were not clearly related to temperature change but were primarily explained by an increase in the amount of manmade lakes suitable for wintering and a higher predation mortality of migratory individuals, respectively. Thus, the predicted changes in PoR caused by increased winter temperatures are still poorly supported by observations.

In this study, we examined two related questions regarding PoR in 27 partially migratory bird species. First, we examined if two extrinsic environmental variables — temperature or seed crop — explained the inter-annual variation in PoR. We investigated the not mutually exclusive effects of two different kinds of temperature variables: the temperature at the beginning of the overwintering season (hereafter early-winter temperature) and the temperature of the previous winter. If PoR would be affected by early-winter temperature, it would support the idea of direct temperature effect on birds when they are deciding on whether to migrate or not (Lehikoinen *et al.* 2013). The effect of previous winter's temperature would imply either a natural selection by better (or worse) fitness of the resident part of the population compared with the migrating part, or a learned behavioural response by individuals that had successfully stayed resident during the previous winter. We quantified the seed crop of three tree species which provide the most exploited food source for overwintering frugivorous birds in Finland. We expected a positive relationship between seed abundance and annual PoR in several species. Our analyses

also accounted for the breeding success, as PoR may increase after a good breeding success if large number of first-winter birds overwinter close to breeding grounds.

Second, we analysed if PoR and the explanatory extrinsic environmental variables (seed crop and temperature) changed during the 25-year study period and examined if they had similar trends. In addition to analysing each species separately, we also divided them into two functional groups: terrestrial birds and waterbirds.

Material & Methods

Study species, period and area

We selected 27 common partially migratory species of which we had substantial long-term monitoring data of both breeding and winter monitoring schemes in Finland into our analyses (Table S1). We divided the study species into terrestrial birds and waterbirds. All 18 terrestrial species were passerines (*Passeriformes*) while waterbirds comprised two groups: six waterfowl (*Anatidae*) and three gulls (*Laridae*). The study period covers breeding seasons 1986–2010 and winters 1986/1987–2010/2011. Breeding individuals of many study species ringed in the study area have been commonly recovered wintering in Finland (Saurola et al. 2013, Valkama *et al.* 2014).

The northern location of our study area (Finland) is suitable for investigating the changes in the proportions between residents and migrants because the northern edge of the distribution of more than two thirds of our study species is within the study area (Brommer, Lehikoinen & Valkama 2012). Because of the northern location the effect of individuals breeding and migrating from outside the study area on the results is smaller than in more southern areas, but still an unknown proportion of wintering individuals probably arrives annually from the directions between north and east.

Bird population monitoring schemes

The wintering abundance of all species was based on Finnish winter bird monitoring scheme, which is coordinated by the Finnish Museum of Natural History. Annually 500 routes located across Finland and with a mean length of 10 kilometres were surveyed by foot or ski once between 25th December and 7th January (Koskimies & Väisänen 1991; Fig. 1a). Most of the routes were monitored every year, usually by the same person or people. Birds observed along the routes were identified to species level, counted and reported as the number of individuals per km for the year of January (*e.g.* winter 1989/1990 was reported as 1990).

The breeding population sizes of terrestrial birds were estimated by line transect counts and point counts, organized by the Finnish Museum of Natural History. About 150 line transects ca. 6 km in length and ca. 50 point count routes were monitored annually mainly in June (Lehikoinen 2013; Fig. 1b). Breeding population sizes of waterbirds were estimated on the basis of inland waterbird (Pöysä *et al*. 2013) and archipelago birds censuses (Hario & Rintala 2011) organized by the Natural Resources Institute Finland and the Finnish Museum of Natural History. Waterbird censuses were conducted on the lakes and inner bays of the Baltic Sea, whereas archipelago censuses were done on the islands along the Finnish coastline of the Baltic Sea (Koskimies & Väisänen 1991, Fig. 1b). In all breeding bird censuses, individual birds, pairs, nests and local flocks were interpreted into units of pairs, whereas in winter bird censuses the unit was the individual (Table S1).

The spatial coverage of the breeding counts is better in the northern part of the country compared to the wintering counts. However, we do not believe that this is a major problem for two reasons. First, both breeding and wintering abundances of most study species are much lower in the northern part than in the southern part of Finland (Väisänen *et al.* 1998, Väisänen 2003). Second, Lehikoinen (2013) and Fraixedas *et al.* (2015) have earlier shown that there are no temporal trends in the mean latitude of the line transect and winter bird data, and thus the spatial distribution of the censuses has not changed and the ratio between counts should be comparable. We applied similar analyses to breeding waterbird census sites and constant effort sites (see later *breeding success index*).

Breeding success index

Wintering individuals consisted partially of adult birds surveyed during breeding time but also of juvenile

individuals hatched after the summer censuses. To account for the potential bias in our analyses due to inter-annual variation in the proportion of juveniles, we included the *breeding success index* (*BS*) in our analysis as proxy of the effect of juvenile individuals on winter numbers. The breeding success of passerines was estimated using data from Finnish constant effort site scheme (CES), organized by the Finnish Museum of Natural History (1987 onwards, Piha & Haapala 2012).

The protocol closely follows the British CES-scheme (Baillie *et al.* 1986). CES consisted of up to 12 standardized mist-net catches (visits) between May and August from 151 sites. On average, 33 sites were surveyed annually. CES data covered 11 passerine species of 27 study species (Table S1). The breeding success index was calculated from the CES data as the annual probabilities of an individual being juvenile using the binomial model by Robinson *et al.* (2007).

Crop monitoring schemes and weather data

The annual abundance of rowanberries *Sorbus aucuparia* was estimated during the winter bird monitoring scheme using a six-level scale: 1) none, 2) very few, 3) few, 4) moderate, 5) abundant, 6) very abundant (Koskimies & Väisänen 1991). Annual abundances of Norway spruce *Picea abies* seeds and birch (*Betula pendula* and *B. pubescens* combined) male catkins were calculated in seed crop monitoring stands run by the Natural Resources Institute Finland (Hokkanen 2000). The material contains on average 55 spruce stands and 56 birch stands around Finland annually (Hokkanen 2000). In the schemes, the number of spruce cones and male catkins of birches, both of which are highly correlated with the amount of seeds, were used as proxies of the annual seed crop.

We expected that the abundance of seeds or rowanberries would influence in particular those species which use them as a food resource. Spruce seeds are the preferred food for common crossbill *Loxia curvirostra*, rowanberries for common blackbird, fieldfare *Turdus pilaris*, Eurasian bullfinch *Pyrrhula pyrrhula* and brambling *Fringilla montifringilla* and a combination of birch and spruce seeds for Eurasian siskin *Carduelis spinus* and common redpoll *Carduelis flammea* (Reinikainen 1937, Fox *et al.* 2009, Lehikoinen, Väisänen & Hokkanen 2010). Food availability does not only affect the number of wintering birds, but also the timing of

autumn migration which occurs earlier during a low crop situation (Fox et al. 2009). The annual abundance of seeds or rowanberries was defined as crop (*C*), which for rowanberry was calculated as the mean abundance observed at the monitoring sites. For birch and spruce, *C* was calculated as the $\log_{10}$-transformed mean of the annual abundance of catkins or cones observed at the monitoring sites. For non-specialist birds, *C* was defined as the mean of the annual crop of three tree species after they had been scaled to have an average of 0 and a standard deviation of 1. This describes the general crop situation, because the annual seed and rowanberry crops were correlated (Pearson correlations between 0.46 and 0.65; Fig. 2a).

Daily mean temperature data covering Finland with a 10 km grid resolution was obtained from the Finnish Meteorological Institute (Venäläinen *et al.* 2005). We calculated the early- and midwinter temperatures for each species from November to December and from December to February, respectively (Fig. 2b). For the species-specific calculations, we used only those grid cells where a species had been observed at least once in the winter censuses during the whole study period. The midwinter temperature of the previous year was used to account for the evolutionary selection response or learned behaviour to be more (or less) inclined to stay resident due to the temperature-induced success of the previous wintering attempt of resident individuals.

Annual indices of summer and winter bird abundances

The annual abundances of each species from breeding censuses and winter bird counts were modelled into species-specific annual summer and winter abundance indices using TRIM-software (version 3.54, Pannekoek & Van Strien 2005), which was developed for the analysis of time series of counts obtained from monitoring wildlife populations and is commonly used in the European bird monitoring schemes (*e.g.* Gregory *et al.* 2005). TRIM-software applies generalized estimation equations approach for estimating loglinear models. We used TRIM to impute the missing counts of repeatedly surveyed routes or points into our time-series using the option of 'time effects models with overdispersion and serial correlation'. The imputed annual indices were used as the annual summer and winter abundance indices in the latter analyses. Because the method did not allow years to have zero observed individuals, for the common starling *Sturnus vulgaris* with winter 2010/2011 with zero observations we added, before inputting data to TRIM, one individual for the winter census route where the

species had been observed the most times.

In order to examine the relative importance summer and winter indices had on PoR, we compared the species-specific coefficients of variation (CV). In addition, we compared the precisions of summer and winter indices by analysing the differences in the species-specific means of the annual relative standard errors (RSE, the standard error divided by the mean and multiplied by 100). The testing was done using paired t-tests.

Proportion of residents (PoR)

We defined the individuals observed inside Finnish borders during the winter counts as residents, while migrants were the individuals which had migrated away from Finland and therefore were not observed in the winter counts. Our division of individuals into residents and migrants was dictated by the monitoring area (Finland) and therefore was partly an arbitrary one, as it inevitably always is unless the individual choice of leaving or staying inside a breeding territory is monitored. However, the Baltic Sea delineates the main migration direction (south-southwest) and thereby forms a natural barrier for migration, particularly for the terrestrial species.

The annual summer and winter abundance indices from TRIM were used to calculate the annual PoR for each species by dividing the annual winter abundance index by the annual summer abundance index of the preceding summer. Hence, PoR is not a proportion ranging from zero to one, but a proportion relative to the situation in the first year of the study period (1987) *i.e.* base year, whose indices were set to one. Neither does PoR represent the real proportion of residents in the total population. Although the actual proportions of residents were not known, the real proportion of residents in the total population are known to vary a lot among our study species (Koskimies 1993). For example, a large proportion of yellowhammers *Emberiza citrinella* and tits overwinter in Finland, but starlings and reed buntings *Emberiza schoeniclus* primarily spend their winters away from Finland. In order to achieve linearity, *PoR* was $\log_{10}$-transformed.

Analyses of the inter-annual variation in PoR

We applied an information-theoretic approach based on AIC*c* values (Akaike's information criterion for a small sample size, Burnham & Anderson 2002) in order to estimate the importance of explanatory variables (seed crops, breeding success, early-winter temperature and previous midwinter temperature) in explaining the inter-annual variation in PoR. For every species, we constructed a set of eight or sixteen (depending on whether breeding success data was available) competing general linear models with all main-effect combinations of three or four explanatory variables (Table S2). In order to identify general patterns for waterbirds and terrestrial birds as distinct functional groups, we constructed two random-intercept mixed models with the same set of covariates but excluding breeding success data and using species as a random factor with package *nlme* in R (Pinheiro *et al.* 2014). Further, because the feeding opportunities of frugivorous species are strongly affected by tree seed and berry crops which usually vary biannually (Fox *et al.* 2009; Lindén *et al.* 2011, Fig. 2a), we expected PoR of frugivores to be less directly influenced by temperature. Therefore, to exclude a potential bias when including these food-specialists in our comparison of the species of aquatic and terrestrial habitats, we formed a third functional group of terrestrial species whose inter-annual variation in PoR was not explained by tree seeds or berries (hereafter terrestrial non-frugivores, 11 species, Table 1), and examined this group separately. The simplest model (*i.e.* the one with the fewest explanatory variables) within ΔAIC-value of two (Burnham & Anderson 2002), when compared with the lowest value, was considered the most parsimonious and therefore the best model.

To achieve stationarity, we removed long-term trends from the dependent variable (PoR) and all explanatory variables. The trends were analysed as explained below (*Analysis of temporal trends*). We detrended the variables with the most complex model of a trend within ΔAIC-value of two (Table S3, Table S4), because thereby we best ensured linearity between dependent and explanatory variables. Residuals from these detrending procedures were used in the analyses of inter-annual variation in PoR. All variables were also scaled to have an average of 0 and variation of 1. After the model selection procedure, we tested the best models for serial autocorrelation with a lag of 1 year. If significant autocorrelation was found, the data of the species in question was reanalysed with a generalized linear model with normally distributed errors and an autocorrelation parameter (corAR1 in package *nlme*) to examine whether including an autocorrelation parameter qualitatively altered the results.

Analyses of temporal trends

For each species, we used linear regressions to examine temporal trends over the study period (1987–2011) in temperatures, PoR, the components from which PoR was calculated (*i.e.* winter and summer abundances), breeding success, as well as spruce and birch and rowanberry crops. In addition, we also examined linear trends in PoR in three functional groups (waterbirds, terrestrial birds and terrestrial non-frugivores) using random-intercept mixed models with species as the random factor.

To account for multiple testing in all species-specific analyses, we applied false discovery rate method (FDR, Waite & Campbell 2006). We based our interpretation of whether an explanatory variable had an effect on dependent variable on the FDR-adjusted p-values and reported only them in the results (unadjusted p-values can be found in Tables S2–3). All analyses were made with R (version 3.1.0, R Core Team 2014).

Results

There was no trend in latitude of constant effort sites (linear regression, $F_{1,676} = 1.928$, $P = 0.17$), but the annual mean latitude of breeding waterbird census sites shifted significantly southwards ($F_{1,23} = 5.44$, $P = 0.029$. However, this shift was only 57 kilometres in 25 years. The winter indices of species showed larger inter-annual variation than summer indices (mean CV 0.766 and 0.262, $t = 4.852$, $df = 26$, $p < 0.001$; Fig S2; Table S1). In addition, winter indices had lower precision compared to summer indices (mean RSEs 45.8 % and 13.3 %, paired t-test $t = -2.829$, $df = 26$, $p = 0.009$; Table S1)

Early-winter temperature had a positive relationship with the inter-annual variation in PoR in five waterbird species (mute swan *Cygnus olor*, whooper swan *Cygnus cygnus*, tufted duck *Aythya fuligula*, goosander *Mergus merganser* and herring gull *Larus argentatus*), waterbirds as a functional group and one terrestrial birds (common starling, Figs 2c & S1, Tables 1 & S2). High abundance of seeds and/or berries resulted in high PoR in seven terrestrial species (common blackbird, fieldfare, common starling, Eurasian siskin,

common redpoll, common crossbill and Eurasian bullfinch) and terrestrial species as a functional group (Fig. S1, Tables 1 & S2). Breeding success had a positive relationship with PoR only in yellowhammer *Emberiza citrinella* (Fig. S1, Tables 1 & S2). The previous winter's temperature did not explain PoR in any of the species. A significant (negative) autocorrelation was retained only in the best model of Eurasian bullfinch and the autocorrelation parameter had only a minor effect on the parameter values of the model (rowanberry: $b = 0.682 \pm 0.166$, $p < 0.001$, FDR-p = 0.007, autocorrelation parameter phi = –0.517).

During the 25-year study period, PoR increased in five waterbirds (mallard *Anas platyrhynchos*, tufted duck, common goldeneye *Bucephala clangula*, goosander and great black-backed gull *Larus marinus*), and in waterbirds as a group (Fig. S2, Tables 2 & S3). PoR decreased in one terrestrial species (greenfinch *Carduelis chloris*), but significant effect was not found either in group of terrestrial species or in terrestrial non-frugivores (Fig. S2, Tables 2 & S3). The model assuming non-linear trend in PoR was superior for great black-backed gull and in waterbirds as a group (Table S3). To make the between-species comparison easier, Table 2 only shows the linear models.

Seed and berry abundances (Fig. 1a), midwinter temperatures or early-winter temperatures showed no temporal trend during our study period (1987–2011; Fig. 1b, Table S4). Winter abundance increased in 12 species and decreased in 4 species; summer abundance increased in 10 species and decreased in 8 species (Table S5).

Discussion

This study provided the first multi-species overview of changes in PoR and relatedness of these changes to environmental factors in partially migratory animals. The findings suggest that direct plastic responses in relation to environmental fluctuation are more important explaining the inter-annual variation in PoR than evolutionary responses measured as delayed effect of the previous winter, but the increasing trend of PoR in waterbirds might had been caused by selective response to the lack of severe winters during the study period. In addition, the species of aquatic and terrestrial habitats differed from each other in both long-term trends in PoR and environmental factors causing the inter-annual variation in PoR. Furthermore, breeding success had hardly

any effect on PoR (one species out of 11).

Direct plastic responses – impact of temperature

We found that early-winter temperature explains the inter-annual variation in PoR in five of nine waterbird species. Winter temperature is highly correlated with the occurrence and extent of ice-cover in the Baltic Sea (Luomaranta *et al.* 2014), which is the most probable causal link between the early-winter temperature and PoR in waterbirds. The migration period of the waterbird species overlaps with the freezing of lakes and coastal areas of the Baltic Sea (Lehikoinen & Jaatinen 2012) and therefore the early-winter temperature can directly affect the migration decision and behaviour of individuals.

In contrast to waterbirds, the PoR of land bird species was generally not affected by temperature fluctuation (except common starling, out of 18 species). The most probable explanation for this is that food availability of these species is not strongly directly temperature related. Many of them either commonly exploit bird feeders (blue tit, great tit, chaffinch *Fringilla coelebs*, brambling, greenfinch, yellowhammer, Väisänen 1994), or are urban dwellers (hooded crow *Corvus corone cornix* and jackdaw *Corvus monedula*, Jokimäki & Suhonen 1998). These species are, similar to frugivores, able to find enough food to survive even during the most severe winters (Hildén & Koskimies 1969). The lack of temperature effect in reed bunting *Emberiza schoeniclus* was probably due to its dependency on seed crop of Common Reed *Phragmites australis* (Matessi *et al.* 2002).

Direct plastic responses – impact of seed and berry crop

In our study, the PoR of 7 out of 18 terrestrial species was connected to tree seed crops. This was expected because it is well documented that migration of many frugivorous species depend on the annual crop (e.g. Fox et al. 2009). Because of the strong relationship between crops and PoR, we believe the lack of long-term trends in rowan, spruce or birch crops explain the lack of trends in PoR in these species (Wallenius 1999; Lindén *et al.*

2011). Furthermore, inter- or intra-specific food competition could affect the PoR of species. To understand this properly the food availability (including alternative food items) as well species-specific per capita consumption rates should be measured.

Some caution is necessary when interpreting the results as variation in proportion of residents, because we used count data of unmarked individuals and cannot know the proportion of the wintering individuals that originated outside Finland. Still, the interpretation should be rather robust because the relationships between temperature or seed crop and PoR were dominated by the variation in winter abundance, and it is probable that the response of wintering behaviour to environmental variation is similar regardless whether the individuals originate from inside or outside Finland.

The increasing trend in PoR in waterbirds

PoR had an increasing trend in waterbirds despite the lack of a respective positive trend in winter temperatures during the study period. The increase in PoR may have been caused by a longer-term climate warming which caused mean and minimum midwinter temperatures to remain at a higher level during the whole study period than in the previous decades (Luomaranta *et al.* 2014). This would have caused the extent of ice cover to remain below the threshold when it was on average beneficial to try to overwinter in Finland (Lehikoinen *et al.* 2013). During the colder winters, more individuals were forced to migrate south causing a decrease in PoR (Lehikoinen *et al.* 2013), but this apparently had no effect on the overall success of the strategy of trying to winter in Finland, because the proportion of individuals utilizing this strategy increased year after year and independently of previous winter's temperature.

Another potential explanation for the observed trends in waterbirds could be a shift of both wintering and breeding areas towards northeast-east. Such a shift of the whole distribution could increase wintering numbers and decrease breeding numbers, a pattern we found in tufted duck and goosander, which both have extended their winter range towards north-east (Lehikoinen et al. 2013). This would mean that no increase in the

real proportion of residents in the total population per se had occurred, but the apparent increase in PoR had been the consequence of observing proportionally more and more wintering individuals originating from outside Finnish borders. However, this is unlikely to be the whole explanation for the observed pattern in ducks, because female ducks are strongly philopatric but show less fidelity towards wintering sites, and therefore breeding distribution is expected to change much more slowly than wintering distribution (Guillemain *et al.* 2013). Therefore it is plausible that the increase in wintering abundance was mostly caused by changes in the migratory behaviour of the Finnish populations. Since the extent of ice cover in the Baltic Sea is expected to decrease dramatically during the next 100 years (Luomaranta *et al.* 2014), we expect the wintering abundances and thereby PoR of waterbirds continue to increase in Finland, but likely also in other high latitude regions.

Selective responses - impact of previous winter's temperature

We found no effect of previous winter's temperature on PoR in any species, which implies that the migration of partial-migrants would be more of a plastic and opportunistic behaviour than a result of temperature related survival of resident individuals. On the other hand, the long-term increase in PoR in waterbirds could had been caused by higher survival of residents causing either a selective or learned response for increased residency. Whether winter temperatures remaining above some threshold was the key for successful wintering and hence the increasing trend in PoR remains unknown, because such an effect is impossible to detect with analyses if the study period does not include winters cold enough to decrease the overwintering success.

The optimal migration decision of an individual could be affected by genetic inclination, social status, physiological condition, environmental conditions, population density or frequency of the two migration strategies (Taylor & Norris 2007; Kokko 2011). For example, a cold winter could cause poor survival of residents after which, assuming frequency-dependent response, the optimal strategy for some individuals from the migratory proportion could be to change their migration strategy and become residents. This kind of mechanism might counterbalance the effect of lower resident survival on PoR and thereby remove the effect of previous winter's temperature. Moreover, if cold temperature-induced poor winter survival leads to a decrease in summer abundance, it makes observing the potential decrease in PoR difficult because both the numerator and

denominator in our PoR calculation are reduced. This is mainly a concern in the species in which a substantial part of the population overwinters in Finland and winter survival is affected by the temperature, like goldcrest and Eurasian treecreeper (Hildén & Koskimies 1969). Furthermore, in several species either early-winter temperature or tree crops affected PoR so strongly that that they could have masked the possible effect of the previous winter. In conclusion, the chances of detecting subtle effects of previous year's temperature on PoR were not very high. Nonetheless, we can conclude that the effect of previous winter's temperature on the inter-annual variation in PoR was smaller than the direct effect of the environmental conditions just before a winter. A study following individuals for multiple years would be needed to conclusively find out the relative importance of innate mechanisms and environmental forcing on migration decisions.

The differences between waterbirds and terrestrial birds

In several terrestrial species PoR did not change despite winter abundance increased, because summer abundance increased at an equal rate. This suggests migration remained the optimal strategy for a similar proportion of individuals as before. All these species are feeder exploiters whose winter food availability improved as bird feeding became more common during the study period (Väisänen 2008), so improved winter survival rate of residents leading to an increase in PoR would had been expected. A potential explanation for the lack of increase in PoR is that birth rate increased equally to the increase in winter survival of residents (Griswold, Taylor & Norris 2011), possibly because improved pre-breeding condition of wintering residents allowed them to breed earlier and lay larger clutches. Another, not mutually exclusive explanation is that the increase in April temperatures during the study period (Lehikoinen et al. 2009) enabled individuals to breed earlier (Meller, Lehikoinen & Vähätalo 2013) and lengthened the breeding season increasing second breeding attempts (Halupka, Dyrcz, & Borowiec, 2008). These mechanisms might have contributed to the decreasing trend in PoR found in greenfinch, but ultimately the reason for the observed decrease remains unknown.

Another possibility is that PoR actually increased in these species, but we failed to observe this with the methodology applied. If an increase in summer abundance was mostly caused by an increase in abundance of residents due to their improved winter survival, it would increase both numerator (winter abundance) and

405 denominator (summer abundance) in our PoR calculation and thereby mask part of the increase in PoR. The
406 greater the proportion of resident individuals was at the beginning of the study period, the more potential there
407 was for this methodological problem to affect our ability to detect changes in PoR. However, comparing the
408 migration numbers (Lehikoinen *et al.* 2008) of the species with the most potential for a masked increase in PoR
409 (great tit, blue tit and jackdaw) to the changes in breeding abundance shows that both increased at a similar rate
410 during the study period. Thereby this alternative method for analysing changes in PoR (Nilsson et al. 2006)
411 suggests that PoR indeed did not change in these species.

412 The higher variation of winter than summer indices means that in most species the variation in PoR was
413 more affected by, and in some almost completely determined by, winter abundances. The lower precision of the
414 winter indices, especially found in some waterbirds and frugivorous species, was caused by the high inter-annual
415 variation in how individuals were distributed between the routes during the counts. This was probably due to
416 flocking behaviour and mobile foraging strategies of opportunistically adjusting to spatiotemporal changes in
417 food availability (Newton 1998). The relatively low precision of winter indices did not mask the strong
418 relationships we found between the environmental variables and PoR, but it might have caused us not to detect
419 more subtle connections.

420 Most of our study species have either different trends during summer and winter, or only a small
421 proportion of individuals overwinter in Finland (Koskimies 1993). Therefore we are confident that if an overall
422 change in PoR in all terrestrial species or non-frugivorous terrestrial species had occurred, we would had been
423 able to detect it.

424 The dependence of waterbirds on non-frozen water is the most potential cause for the observed
425 difference in sensitivity to the temperature between waterbirds and terrestrial species. The food of most
426 terrestrial species wintering in Finland (seeds, berries, feeding sites and other anthropogenic food, dormant
427 invertebrates) is only a little affected by changes in the winter temperature, while if ice covers all shallow waters,
428 feeding becomes impossible for waterbirds. On the other hand, when temperature rises over a certain threshold,
429 then the lack of ice may change the wintering possibilities of waterbirds abruptly from impossible to excellent,
430 because the availability of their underwater food is dictated almost only by the existence of ice.

The occurrence of snow and frost below zero temperature decrease the success of feeding of many terrestrial species as well. Thus, most breeding birds, especially the species feeding on invertebrates, seldom or never try to winter in Finland. Therefore we do not state that the wintering of waterbirds would be generally more temperature dependent than terrestrial birds, even though the difference was clear in our study. Phylogenetical differences (all terrestrial birds were passerines) and smaller size of most terrestrial species in our study compared with waterbirds may also have contributed to the observed differences.

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Data accessibility

Data is archived in Dryad: doi:10.5061/dryad.js17t

References

Adriaensen, F., Ulenaers, P. & Dhondt, A.A. (1993) Ringing recoveries and the increase in numbers of European Great Crested Grebe Podiceps cristatus. *Ardea*, **81**, 59–70.

Alerstam, T. (1990) *Bird Migration*. Cambridge University Press, Cambridge.

Baillie, S.R., Green, R.E., Boddy, M. & Buckland, S.T. (1986) *An Evaluation of the Constant Effort Site Scheme*. Norfolk, UK.

Berthold, P., Mohr, G. & Querner, U. (1990) Control and evolutionary potential of obligate partial migration

results of a two way selective breeding experiment with the blackcap Sylvia atricapilla. *Journal für Ornithologie*, **131**, 33–46.

Berthold, P. (2001) *Bird Migration: a General Survey*. Oxford University Press, Oxford.

Brommer, J.E., Lehikoinen, A. & Valkama, J. (2012) The Breeding Ranges of Central European and Arctic Bird Species Move Poleward. *PloS one*, **7(9)**: e43648.

Burnham, K.P. & Anderson, D.R. (2002) *Model Selection and Multimodel Inference: a Practical Information-theoretic Approach*, 2nd ed. Springer, USA.

Fox, A.D., Kobro, S., Lehikoinen, A., Lyngs, P. & Väisänen, R.A. (2009) Northern Bullfinch Pyrrhula p. pyrrhula irruptive behaviour linked to rowanberry Sorbus aucuparia abundance. *Ornis Fennica*, **86**, 51–60.

Fraixedas, S., Lehikoinen, A. & Lindén, A. (2015) Impacts of climate and land-use on wintering bird populations in Finland. *Journal of Avian Biology*, **46**, 63-72.

Gregory, R.D., Van Strien, A., Vorisek, P., Gmelig Meyling, A.W., Noble, D.G., Foppen, R.P.B. & Gibbons, D.W. (2005) Developing indicators for European birds. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, **360**, 269–88.

Griswold, C.K., Taylor, C.M. & Norris, D.R. (2011) The equilibrium population size of a partially migratory population and its response to environmental change. *Oikos*, **120**, 1847–1859.

Guillemain, M., Pöysä, H., Fox, A.D., Arzel, C., Dessborn, L., Ekroos, J., Gunnarsson, G., Holm, T.E., Christensen, T.K., Lehikoinen, A., Mitchell, C., Rintala, J. & Møller, A.P. (2013) Effects of climate change on European ducks : what do we know and what do we need to know? *Wildlife Biology*, **19**, 1–16.

Haila, Y., Tiainen, J. & Vepsäläinen, K. (1986) Delayed autumn migration as an adaptive strategy of birds in northern Europe: evidence from Finland. *Ornis Fennica*, **63**, 1–9.

Halupka, L., Dyrcz, A., & Borowiec, M. (2008). Climate change affects breeding of reed warblers Acrocephalus scirpaceus. *Journal of Avian Biology*, ***39***, 95–100.

Hario, M. & Rintala, J. (2011) Population trends of the archipelago birds along Finnish coasts during 1986-2010

(in Finnish with English summary). *Linnut-vuosikirja 2010*, **40**–51.

Hebblewhite, M. & Merrill, E.H. (2011) Demographic balancing of migrant and resident elk in a partially migratory population through forage-predation tradeoffs. *Oikos*, **120**, 1860–1870.

Hildén, O. & Koskimies, J. (1969) Effects of the Severe Winter of 1965/66 upon Winter Bird Fauna in Finland. *Ornis Fennica*, **46**, 22–31.

Hokkanen, T. (2000) Seed crops and seed crop forecasts for a number of tree species. In: Mälkönen, E., Babich, N.A., Krutov, V.I. & Markova, I.A. (eds.). Forest Regeneration in the Northern Parts of Europe. *The Finnish Forest Research Institute, Research Papers*, **790**, 87–97.

IPCC, Van Oldenborgh, G.J., Collins, M., Arblaster, J., Christensen, J.H., Marotzke, J., Power, S.B., Rummukainen, M. & Zhou, T. (eds) (2013) *Annex I: Atlas of Global and Regional Climate Projections. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*.

Jokimäki, J. & Suhonen, J. (1998) Distribution and habitat selection of wintering birds in urban environments. *Landscape and Urban Planning*, **39**, 253–263.

Kaitala, A., Kaitala, V. & Lundberg, P. (1993) A Theory of Partial Migration. *The American Naturalist*, **142**, 59–81.

Kokko, H. (2011) Directions in modelling partial migration: how adaptation can cause a population decline and why the rules of territory acquisition matter. *Oikos*, **120**, 1826–1837.

Koskimies, P. (1993) Population sizes and recent trends of breeding and wintering birds in Finland (in Finnish with English summary). *Linnut*, **28**, 6-15.

Koskimies, P. & Väisänen, R.A. (1991) *Monitoring Bird Populations - A Manual of Methods Applied in Finland*. Uusikaupunki.

Lehikoinen, A. (2013) Climate change, phenology and species detectability in a monitoring scheme. *Population Ecology*, **55**, 315–323.

Lehikoinen, A., Ekroos, J., Jaatinen, K., Lehikoinen, P., Lindén, A., Piha, M., Vattulainen, A. & Vähätalo, A.V. (2008) Bird population trends based on the data of Hanko Bird Observatory (Finland) during 1979-2007 (in Finnish with English summary). *Tringa*, **35**: 146–209.

Lehikoinen, A. & Jaatinen, K. (2012) Delayed autumn migration in northern European waterfowl. *Journal of Ornithology*, **153**, 563–570.

Lehikoinen, A., Jaatinen, K., Vähätalo, A. V, Clausen, P., Crowe, O., Deceuninck, B., Hearn, R., Holt, C.A., Hornman, M., Keller, V., Nilsson, L., Langendoen, T., Tománková, I., Wahl, J. & Fox, A.D. (2013) Rapid climate driven shifts in wintering distributions of three common waterbird species. *Global Change Biology* **19**, 2071–2081.

Lehikoinen, A., Väisänen, R.A. & Hokkanen, T. (2010) Variation of abundance in 14 bird species in relation to the seed and berry crop of trees in Finland in winters 1957-2009 (in Finnish with English summary). *Linnut-vuosikirja* **2009**, 90–99.

Lindén, A., Lehikoinen, A., Hokkanen, T. & Väisänen, R. A. (2011) Modelling irruptions and population dynamics of the great spotted woodpecker - joint effects of density and cone crops. *Oikos*, **120**, 1065–1075.

Love, O.P., Gilchrist, H.G., Descamps, S., Semeniuk, C.A.D. & Bêty, J. (2010) Pre-laying climatic cues can time reproduction to optimally match offspring hatching and ice conditions in an Arctic marine bird. *Global Change Biology*, **164**, 277–286.

Luomaranta, A., Ruosteenoja, K., Jylhä, K., Gregow, H., Haapala, J. & Laaksonen, A. (2014) Multimodel estimates of the changes in the Baltic Sea ice cover during the present century. *Tellus*, **66**, 22617.

Matessi, G., Griggio, M., Pilastro, A., Biologia, D., Padova, U. & Bassi, U.B. (2002) The geographical distribution of populations of the large-billed subspecies of reed bunting matches that of its main winter food. *Biological Journal of the Linnean Society*, **75**, 21–26.

Newton, I. (1998) Population limitation in birds. Academic, London.

Newton, I. & Dale, L. (1996) Relationship Between Migration and Latitude Among West European Birds. *Journal of Animal Ecology*, **65**, 137–146.

Nilsson, A.L.K., Lindström, Å., Jonzén, N., Nilsson, S.G. & Karlsson, L. (2006) The effect of climate change on partial migration? the blue tit paradox. *Global Change Biology*, **12**, 2014–2022.

Pannekoek, J. & Van Strien, A. J. (2005) TRIM 3 manual. Trends and indices for monitoring data. CBS, Statistics Netherlands, Voorburg, Netherlands.

Parmesan, C. (2006) Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics*, **37**, 637–669.

Piha, M. & Haapala, J. (2012) Constant Effort Sites in Finland: Population and productivity indices 1987-2011 (in Finnish with English summary). *Linnut-vuosikirja* **2011**, 82–87.

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D. & R Core Team. (2014) nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-117.

Pulido, F. (2011) Evolutionary genetics of partial migration - the threshold model of migration revis(it)ed. *Oikos*, **120**, 1776–1783.

Pöysä, H., Rintala, J., Lehikoinen, A., & Väisänen, R.A. (2013) The importance of hunting pressure, habitat preference and life history for population trends of breeding waterbirds in Finland. European Journal of Wildlife Research, **59**, 245–256.

R Core Team. (2014) R: A language and environment for statistical computing.

Reinikainen, A. (1937) The irregular migrations of the Crossbill, Loxia c. curvirostra, and their relation to the cone-crop of the Conifers. *Ornis Fennica*, **14**, 55–64.

Robinson, R.A., Baillie, S.R. & Crick, H.Q.P. (2007) Weather-dependent survival: implications of climate change for passerine population processes. *Ibis*, **149**, 357–364.

Robinson, R.A., Freeman, S.N., Balmer, D.E. & Grantham, M.J. (2007) Cetti's Warbler Cettia cetti: analysis of an expanding population: Capsule Productivity in the UK Cetti's Warbler population is constant, but overwinter survival has become increasingly dependent on winter temperatures. *Bird Study*, **54**, 230–235.

Saurola, P., Valkama, J. & Velmala, J. (2013) The Finnish Bird Ringing Atlas. Vol. 1. Finnish Museum of Natural

History and Finnish Ministry of Environment.

Sillett, T.S. & Holmes, R.T. (2002) Variation in Survivorship of a Migratory Songbird throughout Its Annual Cycle. *Journal of Animal Ecology*, **71**, 296–308.

Taylor, C.M. & Norris, D.R. (2007) Predicting conditions for migration: effects of density dependence and habitat quality. *Biology letters*, **3**, 280–283.

Terrill, S.B. & Able, K.B. (1988) Bird Migration Terminology. *The Auk*, **105**, 205–206.

Valkama, J., Saurola, P., Lehikoinen, A., Lehikoinen, E., Piha, M., Sola, P. & Velmala, W. (2014) The Finnish Bird Ringing Atlas. Vol. 2. Finnish Museum of Natural History and Finnish Ministry of Environment.

Venäläinen, A., Tuomenvirta, H., Pirinen, P. & Drebs, A. (2005) A Basic Finnish Climate Data Set 1961-2000 - Description and Illustrations. *Reports ↓Finnish Meteorological Institute*.

Visser, M.E., Perdeck, A.C., Van Balen, J.H. & Both, C. (2009) Climate change leads to decreasing bird migration distances. *Global Change Biology*, **15**, 1859–1865.

Vliet, J. Van, Musters, C.J.M. & Keurs, J. Ter. (2009) Changes in migration behaviour of Blackbirds Turdus merula from the Netherlands. *Bird Study*, **56**, 276–281.

Väisänen, R.A. (1994) Abundance of the 58 most common bird species at winter feeding sites in Finland (in Finnish with English summary). *Linnut*, **29**, 16–23.

Väisänen, R.A. (2003) Regional population trends of 33 common bird species in Finland during 27 winters (in Finnish with English summary). *Linnut-vuosikirja,* **2002**, 60–79.

Väisänen, R.A. (2008) Changes in frequency and abundance of 63 bird species at winter feeding sites in Finland during 19 winters 1998/1989-2006/2007 (in Finnish with English summary). *Linnut-vuosikirja,* **2007**, 60–79.

Väisänen, R.A., Lammi, E. & Koskimies, P. (1998) Distribution, numbers and population changes of Finnish breeding birds (Muuttuva pesimälinnusto). Otavan kirjapaino, Keuruu.

Waite, T.A. & Campbell, L.G. (2006) Controlling the false discovery rate and increasing statistical power in

ecological studies. *Ecoscience*, **13**, 439–442.

Wallenius, T.H. (1999) Yield variations of some common wild berries in Finland in 1956 – 1996. *Annales Botanici Fennici*, **36**, 299–314.

Supporting Information

The following Supporting Information is available for this article online

Table S1. Annual sample sizes of bird censuses.

Table S2. All models explaining the annual variation in PoR.

Table S3. All models of trends in PoR.

Table S4. All models of trends in tree crops and winter temperatures.

Table S5. Trends in winter and summer abundances.

Fig. S1. All significant effects the explanatory variables on annual PoR.

Fig. S2. The annual indices of the winter abundance, summer abundance and PoR.

Table 1. The best models, according to a model selection process, for explaining the inter-annual variation in proportion of residents (PoR) in 27 partially migratory bird species, and waterbirds (W), all terrestrial birds (T) and terrestrial non-frugivorous (T nf) birds as groups. CES denotes whether constant effort site data for calculating a breeding success index was available and used in the model selection process of a species. The species-specific p-values are adjusted for false discovery rate. See text and Table S2 for details.

Species	n	Group	CES	r^2	The best model	b ± SE	p
Waterbirds	225	W	no	–	Early-winter temperature	0.47 ± 0.06	<0.001
Terrestrial birds	450	T	no	–	Tree seed & berry crop	0.37 ± 0.04	<0.001
Terrestrial non-frugivores	275	T nf	no	–	Null model	–	–
Mute swan	25	W	no	0.44	Early-winter temperature	0.66 ± 0.16	0.005
Whooper swan	25	W	no	0.56	Early-winter temperature	0.75 ± 0.14	<0.001
Mallard	25	W	no	–	Null model	–	–
Tufted duck	25	W	no	0.33	Early-winter temperature	0.57 ± 0.17	0.033
Common goldeneye	25	W	no	–	Null model	–	–
Goosander	25	W	no	0.50	Early-winter temperature	0.71 ± 0.15	0.002
Mew gull	25	W	no	0.26	Early-winter temperature	0.51 ± 0.18	0.090
Herring gull	25	W	no	0.36	Early-winter temperature	0.60 ± 0.17	0.019
Great black-backed gull	25	W	no	–	Null model	–	–
Common blackbird	24	T	yes	0.68	Tree seed or berry crop	0.83 ± 0.12	<0.001
Fieldfare	24	T	yes	0.84	Tree seed or berry crop	0.92 ± 0.08	<0.001
Goldcrest	25	T nf	no	0.23	Tree seed or berry crop	0.48 ± 0.18	0.119
Blue tit	24	T nf	yes	0.41	Previous winter's temperature	0.39 ± 0.17	0.243
					Breeding success	0.43 ± 0.17	0.158
Great tit	24	T nf	yes	–	Null model	–	–
Eurasian treecreeper	24	T nf	yes	–	Null model	–	–
Jackdaw	25	T nf	no	–	Null model	–	–
Hooded crow	25	T nf	no	–	Null model	–	–
Common starling	25	T	no	0.68	Tree seed or berry crop	0.49 ± 0.13	0.010
					Previous winter's temperature	0.35 ± 0.13	0.101
					Early-winter temperature	0.54 ± 0.12	0.004
Chaffinch	24	T nf	yes	0.43	Tree seed or berry crop	0.52 ± 0.17	0.054
					Previous winter's temperature	-0.47 ± 0.17	0.097
Brambling	25	T nf	no	0.25	Tree seed or berry crop	0.50 ± 0.18	0.094
Greenfinch	24	T nf	yes	–	Null model	–	–
Eurasian siskin	24	T	yes	0.73	Tree seed or berry crop	0.86 ± 0.11	<0.001
Common redpoll	25	T	no	0.65	Tree seed or berry crop	0.76 ± 0.13	<0.001
					Previous winter's temperature	0.29 ± 0.13	0.220
Common crossbill	25	T	no	0.62	Tree seed or berry crop	0.79 ± 0.13	<0.001
Eurasian bullfinch	24	T	yes	0.55	Tree seed or berry crop	0.74 ± 0.14	0.001

Yellowhammer	24	T nf	yes	0.58	Breeding success	0.76 ± 0.14	<0.001
Reed bunting	24	T nf	yes	–	Null model	–	–

597 Table 2. Trends in proportion of residents (PoR) in 27 partially migratory bird species, and in waterbirds (W), all
598 terrestrial birds (T) and terrestrial non-frugivorous birds (T nf) as groups. The change in PoR during the study
599 period is presented as a percentage change from 1987 to 2011. The species-specific p-values are adjusted for
600 false discovery rate.

Species	Group	r^2	Trend	b ± SE	p
Waterbirds	W	–	Incease (+342%)	0.027 ± 0.004	<0.001
Terrestrial birds, all	T	–	No change	-0.001 ± 0.003	0.769
Terrestrial birds, non-frugivores	T nf	–	No change	-0.001 ± 0.002	0.612
Mute swan	W	0.19	No change	-0.013 ± 0.006	0.135
Whooper swan	W	0.07	No change	-0.012 ± 0.009	0.432
Mallard	W	0.44	Increase (+55%)	0.008 ± 0.002	0.003
Tufted duck	W	0.68	Incease (+33590%)	0.105 ± 0.015	<0.001
Common goldeneye	W	0.92	Increase (+4895%)	0.071 ± 0.004	<0.001
Goosander	W	0.60	Incease (+364%)	0.028 ± 0.005	<0.001
Mew gull	W	0.01	No change	0.007 ± 0.012	0.810
Herring gull	W	0.12	No change	0.020 ± 0.011	0.281
Great black-backed gull	W	0.41	Increase (+580%)	0.029 ± 0.007	0.005
Common blackbird	T	0.06	No change	0.010 ± 0.008	0.442
Fieldfare	T	0.00	No change	-0.003 ± 0.033	0.999
Goldcrest	T nf	0.07	No change	-0.005 ± 0.004	0.442
Blue tit	T nf	0.10	No change	0.003 ± 0.002	0.326
Great tit	T nf	0.15	No change	-0.004 ± 0.002	0.224
Eurasian treecreeper	T nf	0.07	No change	-0.003 ± 0.003	0.442
Jackdaw	T nf	0.00	No change	-0.000 ± 0.004	0.999
Hooded crow	T nf	0.10	No change	0.002 ± 0.001	0.327
Common starling	T	0.03	No change	-0.014 ± 0.016	0.658
Chaffinch	T nf	0.00	No change	0.001 ± 0.008	0.999
Brambling	T nf	0.00	No change	-0.000 ± 0.013	0.999
Greenfinch	T nf	0.34	Decrease (-39%)	-0.009 ± 0.003	0.018
Eurasian siskin	T	0.04	No change	0.018 ± 0.020	0.658
Common redpoll	T	0.00	No change	-0.001 ± 0.014	0.999
Common crossbill	T	0.00	No change	-0.004 ± 0.023	0.987
Eurasian bullfinch	T	0.12	No change	-0.011 ± 0.006	0.307
Yellowhammer	T nf	0.09	No change	-0.003 ± 0.002	0.380
Reed bunting	T nf	0.01	No change	0.008 ± 0.016	0.810

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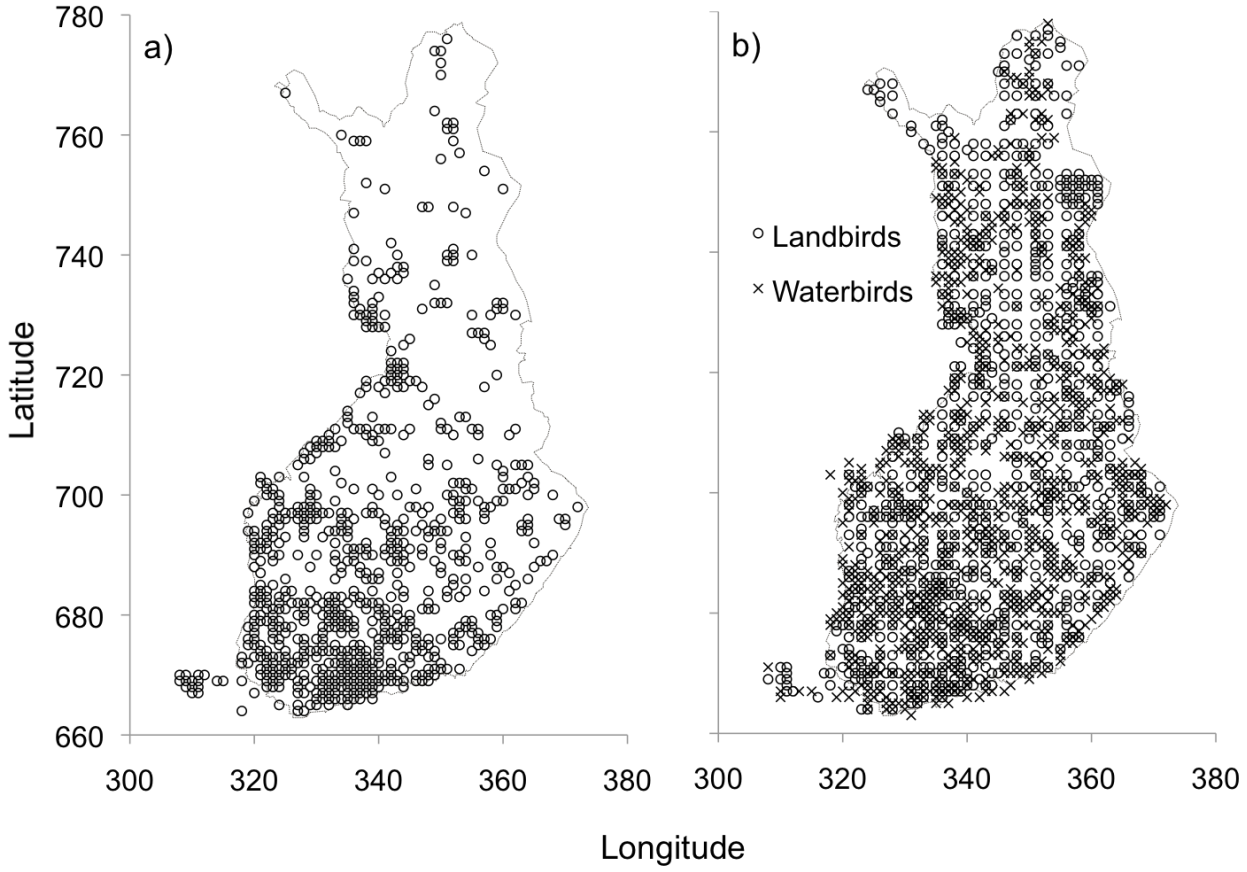

603

604 Figure 1. Spatial distribution of a) winter and b) summer count sites in Finnish uniform coordinate system during
605 1987–2011 and 1986–2010, respectively. The northern part of the country is less intensively covered during the
606 winter time because of very low bird densities and low amount of day light (sun does not rise above the horizon
607 in northern part of the country during winter bird count period). Winter bird counts are covering both waterbirds
608 and land birds simultaneously, which why census sites are shown only using one symbol.

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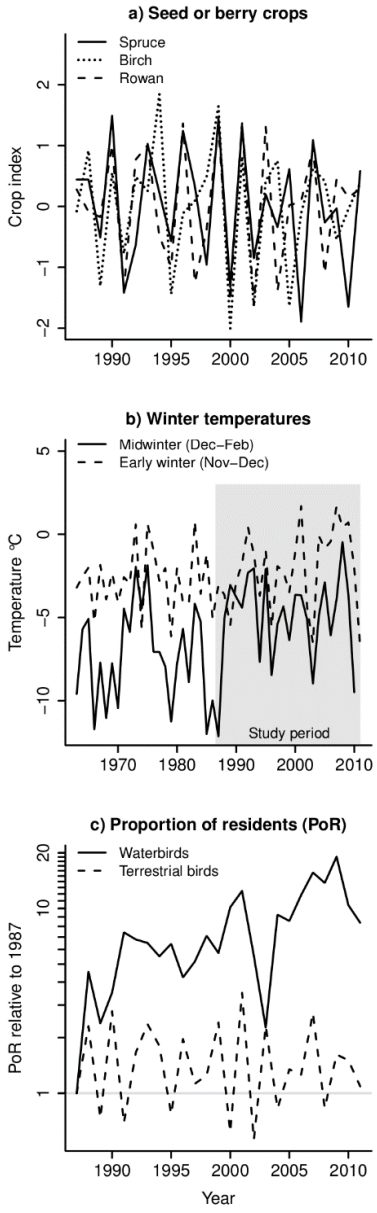
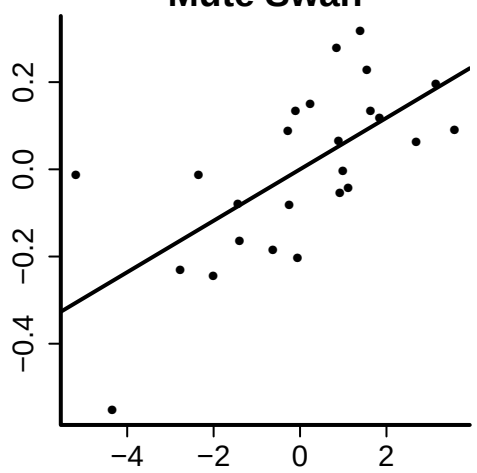


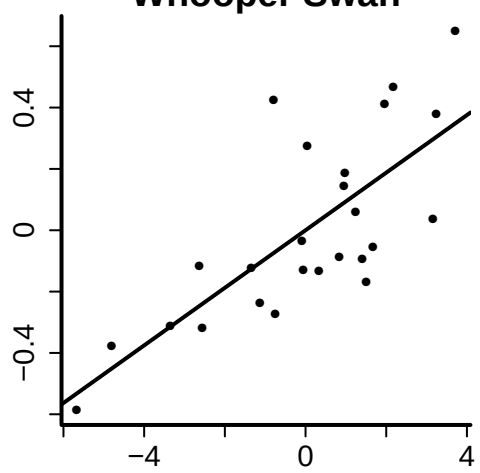
Figure 2. a) The annual seed crop index of spruce (solid line) and birch (dotted line), and annual berry crop index of rowan (dashed line). All crop indices are scaled to have a mean of 0 and variance of 1. b) Annual early-winter (November – December, dashed line) and midwinter (December – February, solid line) temperatures in Finland during 1963–2011. The study period is shadowed. c) The annual means of proportions of residents (PoR) compared with the first year of the study period (1987) in nine waterbirds (solid line) and 21 terrestrial birds (dashed line). The years 1961-1986 were included to illustrate the lack of severe winters during the study period.

Mute Swan



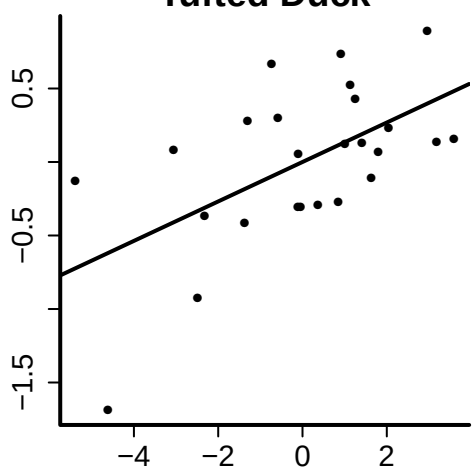
Early−winter temperature °C

Whooper Swan



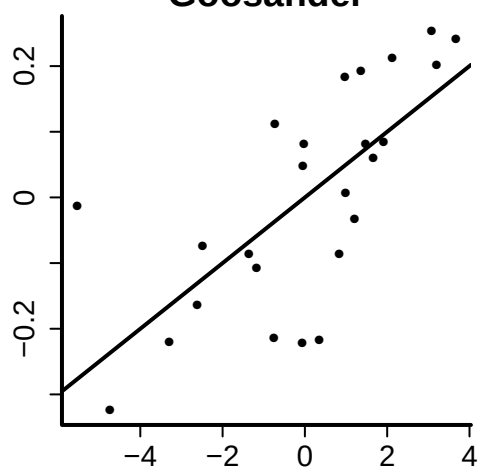
Early−winter temperature °C

Tufted Duck



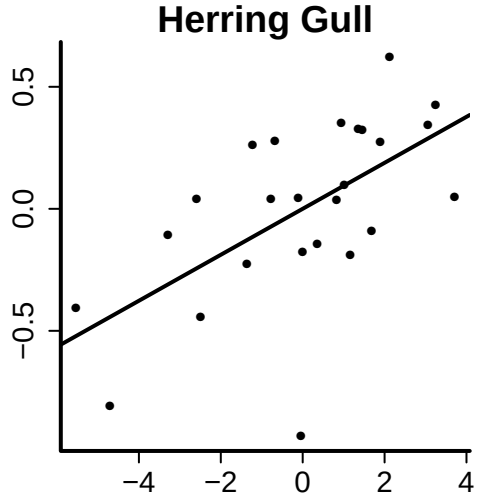
Early−winter temperature °C

Goosander



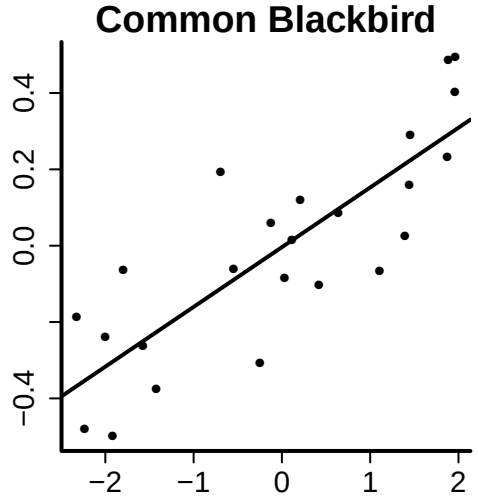
Early−winter temperature °C

Herring Gull



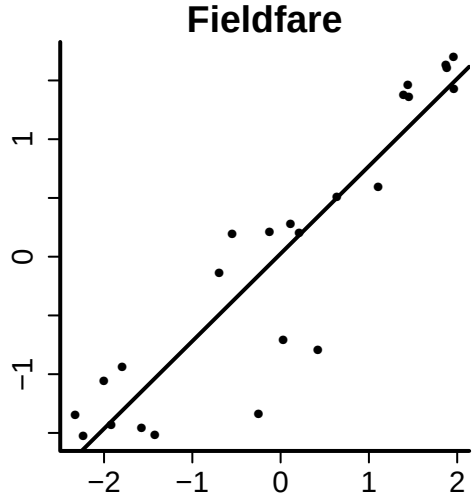
Early−winter temperature °C

Common Blackbird



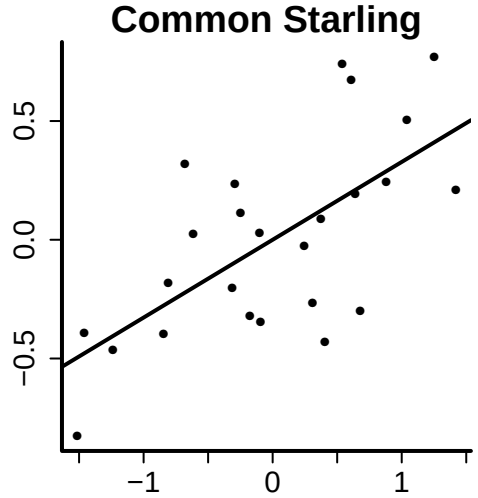
Tree seeds & berries

Fieldfare



Tree seeds & berries

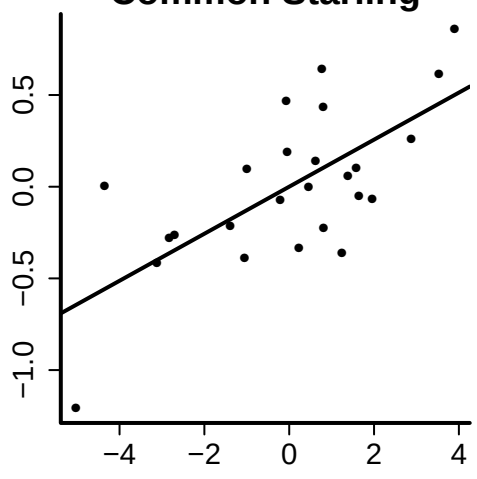
Common Starling



Tree seeds & berries

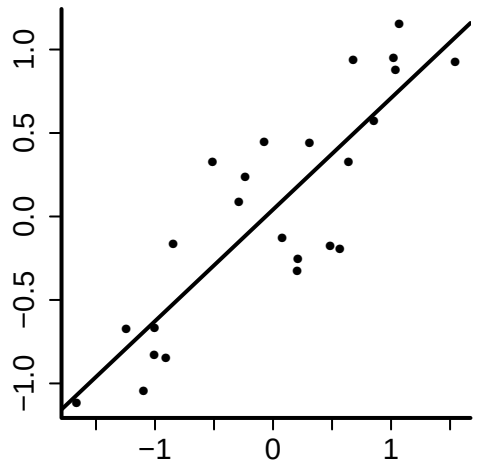
Po

Common Starling



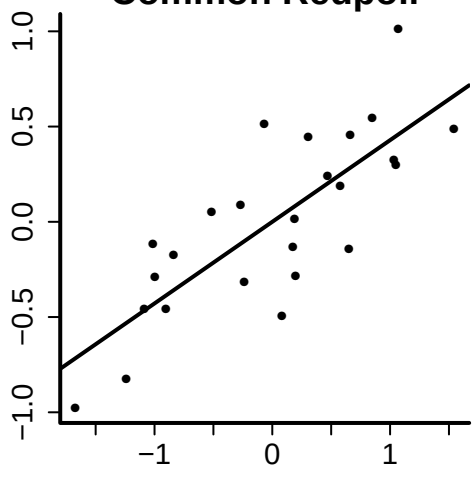
Early−winter temperature °C

Eurasian Siskin



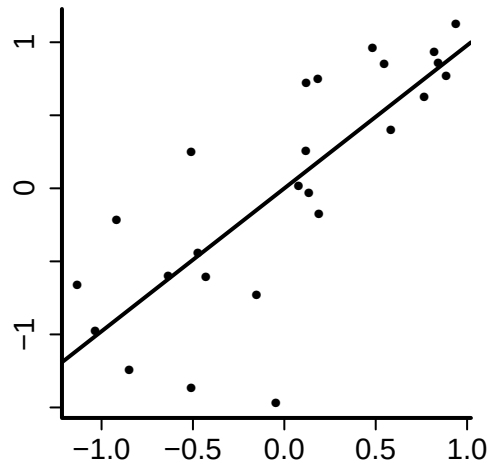
Tree seeds & berries

Common Redpoll



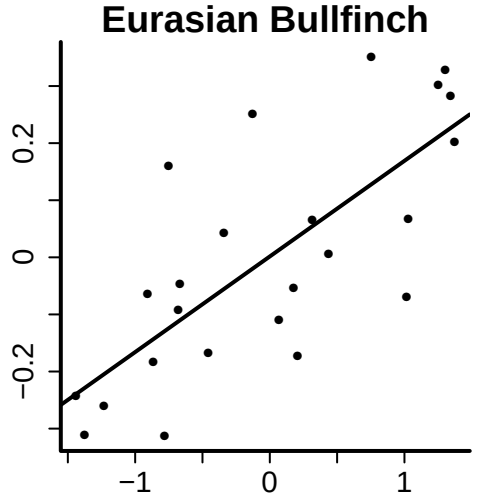
Tree seeds & berries

Common Crossbill



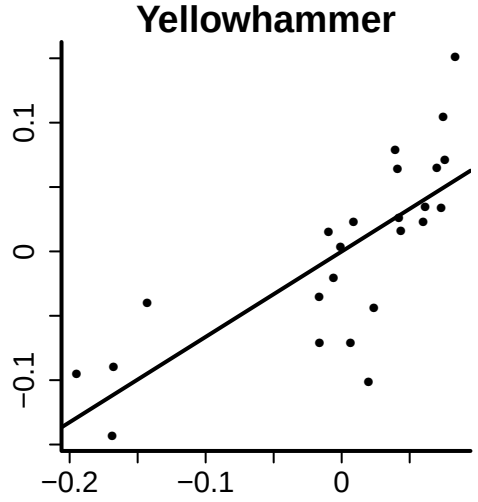
Tree seeds & berries

Eurasian Bullfinch



Tree seeds & berries

Yellowhammer



Breeding success

PoR, summer abundance and winter abundance relative to 1987

Mute Swan

Whooper Swan

Mallard

Tufted Duck

Common Goldeneye

Goosander

Mew Gull

Herring Gull

Great Black−backed Gull

Common Blackbird

Fieldfare

Goldcrest

Blue Tit

Great Tit

Eurasian Treecreeper

Jackdaw

Hooded Crow

Common Starling

Chaffinch

Brambling

Greenfinch

Eurasian Siskin

Common Redpoll

Common Crossbill

Eurasian Bullfinch

Yellowhammer

Reed Bunting

Year

Table S1. Annual sample sizes (mean, min-max) in winter censuses (individuals), breeding censuses (pairs) and constant censuses (pairs) and constant effort site scheme (CES, individuals), as well as coefficients of variation (CV) and means of the annual relative standard errors (RSE) for winter and summer censuses during the 25-year study period (1987–2011).

	Winter census					Summer census					CES-scheme		
Species	Mean	Min	Max	CV	RSE	Mean	Min	Max	CV	RSE	Mean	Min	Max
Mute Swan	881	130	1518	0.34	27.4	195	28	504	0.48	11.7	—	—	—
Whooper Swan	462	43	2642	1.17	43.3	78	0	154	0.62	44.8	—	—	—
Mallard	8835	5027	13700	0.24	9.7	1102	871	1633	0.10	9.7	—	—	—
Tufted duck	4203	9	43471	2.08	233.0	1323	202	2923	0.27	7.4	—	—	—
Common Goldeneye	2311	77	13551	1.20	65.8	1580	1008	2375	0.11	9.3	—	—	—
Goosander	2482	408	5458	0.44	32.5	487	95	1003	0.22	10.7	—	—	—
Mew Gull	1417	40	3508	0.50	87.6	5725	381	9807	0.11	5.4	—	—	—
Herring Gull	6948	190	28102	0.70	62.2	8029	20	12529	0.08	6.1	—	—	—
Great Black-backed Gull	447	30	719	0.35	64.5	470	190	800	0.14	29.8	—	—	—
Common Blackbird	1099	139	2726	0.72	9.8	403	206	899	0.35	11.2	91	31	194
Fieldfare	12480	36	58270	1.55	67.8	1106	612	1767	0.16	7.6	104	35	149
Goldcrest	3009	1366	7294	0.44	7.0	364	185	759	0.31	11.2	—	—	—
Blue Tit	13540	3672	24081	0.39	5.5	232	95	502	0.38	15.3	314	25	602
Great Tit	28979	21308	41976	0.15	2.8	766	306	1581	0.21	6.7	439	153	719
Eurasian Treecreeper	431	236	637	0.25	9.8	78	33	177	0.25	23.1	9	2	20
Jackdaw	8259	3162	19818	0.49	12.9	161	38	368	0.40	22.1	—	—	—
Hooded Crow	12901	9704	19468	0.12	4.8	663	376	1213	0.13	6.8	—	—	—
Common Starling	82	0	707	1.40	72.0	125	59	230	0.21	18.8	—	—	—
Chaffinch	230	45	853	0.72	18.9	5123	2960	9496	0.05	3.1	277	170	437
Brambling	182	17	1034	1.34	46.9	1121	379	3512	0.23	8.0	—	—	—
Greenfinch	20919	7896	37716	0.35	6.9	309	101	838	0.41	15.8	207	49	554
Eurasian Siskin	3157	61	17604	1.33	77.2	1115	609	1964	0.19	7.8	163	40	482
Common Redpoll	13920	1368	82358	1.25	14.9	354	125	930	0.36	15.2	—	—	—
Common Crossbill	932	9	3412	1.16	28.5	391	58	812	0.68	18.2	—	—	—
Eurasian Bullfinch	7654	3269	14375	0.47	5.4	172	95	292	0.35	15.6	39	4	86
Yellowhammer	30544	21846	42403	0.15	5.2	690	355	1304	0.09	6.9	72	28	153
Reed Bunting	26	1	193	1.39	215.4	254	128	399	0.17	10.7	344	159	630

Table S2. All models explaining the annual variation in PoR. Due to waning over-bet the intermodels were always 0 and are not shown. Both unadjusted (U) and false discovery rate (FDR) adjusted p-values are shown. The "Sig" denotes level of information with 4 big (4) and ACI is Akaike's information criterion for small sample size. The best models (the simplest models inside ΔAIC of 2) are bolded

Species	Model	Predictor	B	SE	t / F / Wald	df1	df2	p(U)	p(FDR)	Sig	AICc
Waterbirds	**Early winter temperature**		**0.473**	**0.080**	**5.932**	**1**	**218**	**<0.001**	**<0.001**	***	**580.1**
Waterbirds	**Early winter temperature**		**0.473**	**0.080**	**5.932**	**1**	**218**	**<0.001**	**<0.001**	***	**580.1**
Waterbirds	Tree seed & berry crop		0.364	0.084	4.337	1	218	<0.001	<0.001	***	591.3
Waterbirds	Previous winter's temperature		0.095	0.059	1.605	1	218	>=.1	>=.1		591.3
Waterbirds	Early winter temperature		0.473	0.080	5.932	1	218	<0.001	<0.001	***	580.1
Waterbirds	Early winter temperature		0.473	0.080	5.932	1	218	<0.001	<0.001	***	580.1
Waterbirds	Early winter temperature		0.469	0.084	7.832	<0.001	>=.1				942.5
Waterbirds	Tree seed & berry crop		0.364	0.084	4.337	1	218	<0.001	<0.001	***	942.5
Waterbirds	Previous winter's temperature		0.100	0.067	2.262	0.023	>=.1				580.5
Waterbirds	Early winter temperature		0.473	0.080	5.932	1	218	<0.001	<0.001	***	580.5
Waterbirds	Previous winter's temperature		0.095	0.059	1.605	1	218	>=.1	>=.1		591.3
Terrestrial birds, all	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1265.0
Terrestrial birds, all	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1275.2
Terrestrial birds, all	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1275.2
Terrestrial birds, all	**Tree seed & berry crop**		**0.041**	**0.047**	**0.881**	**0.379**	>=.1	**436**	>=.1		**1257.6**
Terrestrial birds, all	Tree seed & berry crop		0.041	0.047	0.881	0.379	>=.1	436	>=.1		1276.0
Terrestrial birds, all	Previous winter's temperature		0.009	0.047	0.192	0.971	>=.1				
Terrestrial birds, all	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1275.2
Terrestrial birds, all	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1275.2
Terrestrial birds, all	Tree seed & berry crop		0.366	0.044	8.359	0.003	>=.1	430	>=.1		1213.8
Terrestrial birds, all	Previous winter's temperature		0.009	0.047	0.192	0.971	>=.1				
Terrestrial birds, all	**Early winter temperature**		**0.017**	**0.047**	**0.359**	**0.722**	>=.1	**437**	>=.1		**1276.2**
Terrestrial birds, non-flyingcores	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1265.0
Terrestrial birds, non-flyingcores	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1275.2
Terrestrial birds, non-flyingcores	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1275.2
Terrestrial birds, non-flyingcores	Tree seed & berry crop		0.041	0.047	0.881	0.379	>=.1	436	>=.1		1257.6
Terrestrial birds, non-flyingcores	Previous winter's temperature		0.009	0.047	0.192	0.971	>=.1				
Terrestrial birds, non-flyingcores	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1276.2
Terrestrial birds, non-flyingcores	Tree seed & berry crop		0.041	0.047	0.881	0.379	>=.1	436	>=.1		1257.6
Terrestrial birds, non-flyingcores	Previous winter's temperature		0.009	0.047	0.192	0.971	>=.1				
Terrestrial birds, non-flyingcores	Early winter temperature		0.017	0.047	0.359	0.722	>=.1	437	>=.1		1276.2
Mute Swan	**Early winter temperature**		**0.213**	**0.054**	**15.615**	**<0.001**	**0.049**	**1,436**	**0.195**	***	**1,781.1**
Mute Swan	Previous winter's temperature		0.222	0.053	1.562	0.206	0.918	1,436	0.996		2,036.5
Mute Swan	Early winter temperature		0.213	0.054	15.615	<0.001	0.049	1,436	0.195	***	1,781.1
Mute Swan	Early winter temperature		0.213	0.054	15.615	<0.001	0.049	1,436	0.195	***	1,781.1
Mute Swan	Tree seed & berry crop		0.212	0.054	15.564	0.758	0.479	4,115	62.8		
Mute Swan	Previous winter's temperature		0.222	0.053	1.562	0.206	0.918	1,436	0.996		2,036.5
Mute Swan	Early winter temperature		0.213	0.054	15.615	<0.001	0.049	1,436	0.195	***	1,781.1
Mute Swan	Previous winter's temperature		0.141	0.053	0.942	0.307	1.000				
Mute Swan	Tree seed & berry crop		0.212	0.054	15.564	0.758	0.479	4,115	62.8		
Mute Swan	Early winter temperature		0.213	0.054	15.615	<0.001	0.049	1,436	0.195	***	1,781.1
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	**1,268**	0.239	***	1,729.1
Whooper Swan	Previous winter's temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Early winter temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Tree seed & berry crop		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Previous winter's temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Tree seed & berry crop		0.564	0.141	0.941	0.332	1.000	2,1062	0.160	NA	1,964.4
Whooper Swan	Previous winter's temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Tree seed & berry crop		0.564	0.141	0.941	0.332	1.000	2,1062	0.160	NA	1,964.4
Whooper Swan	Tree seed & berry crop		0.560	0.148	0.913	0.343	1.000	2,1062	0.167	61.1	
Whooper Swan	Tree seed & berry crop		0.564	0.141	0.941	0.332	1.000	2,1062	0.160	NA	1,964.4
Mallard	**Intercept only (null model)**		na	na	na	na	na	na	**0.125**	NA	
Mallard	**Early winter temperature**		**0.150**	**0.012**	**0.788**	**0.487**	**1.000**	**1,1072**	**0.777**	**NA**	**2,076.5**
Mallard	Previous winter's temperature		0.150	0.012	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Early winter temperature		0.150	0.012	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Early winter temperature		0.150	0.012	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Tree seed & berry crop		0.150	0.012	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Previous winter's temperature		0.150	0.012	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Early winter temperature		0.150	0.012	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Tree seed & berry crop		0.328	0.014	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Previous winter's temperature		0.150	0.012	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Tree seed & berry crop		0.328	0.014	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Mallard	Tree seed & berry crop		0.328	0.014	0.788	0.487	1.000	1,1072	0.777	NA	2,076.5
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	**1,268**	0.239	***	1,729.1
Whooper Swan	Previous winter's temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Early winter temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Tree seed & berry crop		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Previous winter's temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Tree seed & berry crop		0.564	0.141	0.941	0.332	1.000	2,1062	0.160	NA	1,964.4
Whooper Swan	Previous winter's temperature		0.032	0.208	0.152	0.883	1.000	1,268	0.997		2,035.2
Whooper Swan	Early winter temperature		0.749	0.128	34.197	<0.001	0.049	1,268	0.239	***	1,729.1
Whooper Swan	Tree seed & berry crop		0.564	0.141	0.941	0.332	1.000	2,1062	0.160	NA	1,964.4
Whooper Swan	Tree seed & berry crop		0.560	0.148	0.913	0.343	1.000	2,1062	0.167	61.1	
Whooper Swan	Tree seed & berry crop		0.564	0.141	0.941	0.332	1.000	2,1062	0.160	NA	1,964.4
Tufted duck	**Early winter temperature**		**0.071**	**0.111**	**0.322**	**0.603**	**0.525**	**0.126**	**0.158**	**NA**	**1,964.6**
Tufted duck	Previous winter's temperature		0.171	0.172	0.386	0.535	1.000	0.126	0.303	NA	1,964.6
Tufted duck	Early winter temperature		0.071	0.111	0.322	0.603	0.525	0.126	0.158	NA	1,964.6
Tufted duck	Previous winter's temperature		0.171	0.172	0.386	0.535	1.000	0.126	0.303	NA	1,964.6
Tufted duck	Early winter temperature		0.071	0.111	0.322	0.603	0.525	0.126	0.158	NA	1,964.6
Tufted duck	Tree seed & berry crop		0.166	0.175	1.175	0.278	0.932				
Tufted duck	Previous winter's temperature		0.171	0.172	0.386	0.535	1.000	0.126	0.303	NA	1,964.6
Tufted duck	Early winter temperature		0.071	0.111	0.322	0.603	0.525	0.126	0.158	NA	1,964.6
Tufted duck	Tree seed & berry crop		0.166	0.175	1.175	0.278	0.932				
Tufted duck	Tree seed & berry crop		0.166	0.175	1.175	0.278	0.932				
Common Goldeneye	**Intercept only (null model)**		na	na	na	na	na	na	**0.291**	NA	
Common Goldeneye	Early winter temperature		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Previous winter's temperature		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Early winter temperature		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Early winter temperature		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Tree seed & berry crop		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Previous winter's temperature		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Early winter temperature		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Tree seed & berry crop		0.098	0.213	0.412	0.684	1.000	0.319	0.215	76.6	
Common Goldeneye	Previous winter's temperature		0.105	0.207	0.503	0.520	1.000	0.314	0.396	NA	2,076.3
Common Goldeneye	Tree seed & berry crop		0.098	0.213	0.412	0.684	1.000	0.319	0.215	76.6	
Common Goldeneye	Tree seed & berry crop		0.098	0.213	0.412	0.684	1.000	0.319	0.215	76.6	
Goosander	**Early winter temperature**		**0.178**	**0.218**	**0.348**	**0.556**	**1.000**				
Goosander	Previous winter's temperature		0.178	0.218	0.348	0.556	1.000				
Goosander	**Early winter temperature**		**0.178**	**0.218**	**0.348**	**0.556**	**1.000**				
Goosander	Early winter temperature		0.178	0.218	0.348	0.556	1.000				
Goosander	Tree seed & berry crop		0.326	0.207	0.648	0.422	1.000	0.219	0.359	76.1	
Goosander	Previous winter's temperature		0.178	0.218	0.348	0.556	1.000				
Goosander	Early winter temperature		0.178	0.218	0.348	0.556	1.000				
Goosander	Tree seed & berry crop		0.326	0.207	0.648	0.422	1.000	0.219	0.359	76.1	
Goosander	Previous winter's temperature		0.178	0.218	0.348	0.556	1.000				
Goosander	Early winter temperature		0.178	0.218	0.348	0.556	1.000				
Goosander	Tree seed & berry crop		0.326	0.207	0.648	0.422	1.000	0.219	0.359	76.1	
Goosander	Tree seed & berry crop		0.707	0.194	4.366	<0.001	0.049				
Mew Gull	**Early winter temperature**		**0.179**	**0.037**	**23.104**	**<0.001**	**0.049**	**1,1247**	**0.175**	***	**2,177.1**
Mew Gull	Previous winter's temperature		0.179	0.037	0.317	0.574	1.000	1,1247	0.997	NA	2,179.2
Mew Gull	Early winter temperature		0.179	0.037	23.104	<0.001	0.049	1,1247	0.175	***	2,177.1
Mew Gull	Early winter temperature		0.179	0.037	23.104	<0.001	0.049	1,1247	0.175	***	2,177.1
Mew Gull	Tree seed & berry crop		0.179	0.037	23.104	<0.001	0.049	1,1247	0.175	***	2,177.1
Mew Gull	Previous winter's temperature		0.179	0.037	0.317	0.574	1.000	1,1247	0.997	NA	2,179.2
Mew Gull	Early winter temperature		0.179	0.037	23.104	<0.001	0.049	1,1247	0.175	***	2,177.1
Mew Gull	Tree seed & berry crop		0.071	0.04	4.385	0.764	1.000	2,1252	0.160	71.5	
Mew Gull	Previous winter's temperature		0.179	0.037	0.317	0.574	1.000	1,1247	0.997	NA	2,179.2
Mew Gull	Early winter temperature		0.179	0.037	23.104	<0.001	0.049	1,1247	0.175	***	2,177.1
Mew Gull	Tree seed & berry crop		0.071	0.04	4.385	0.764	1.000	2,1252	0.160	71.5	
Mew Gull	Tree seed & berry crop		0.071	0.04	4.385	0.764	1.000	2,1252	0.160	71.5	
Herring Gull	**Intercept only (null model)**		na	na	na	na	na	na	**0.245**	NA	
Herring Gull	**Early winter temperature**		**0.005**	**0.07**	**0.006**	**0.932**	**0.910**	**1,1249**	**0.996**	NA	**2,247.1**
Herring Gull	Previous winter's temperature		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Tree seed & berry crop		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Previous winter's temperature		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Early winter temperature		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Early winter temperature		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Tree seed & berry crop		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Previous winter's temperature		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Early winter temperature		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Tree seed & berry crop		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Herring Gull	Tree seed & berry crop		0.005	0.07	0.006	0.932	0.910	1,1249	0.996	NA	2,247.1
Great Black-backed Gull	**Intercept only (null model)**		na	na	na	na	na	na	**0.012**	NA	
Great Black-backed Gull	Early winter temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Previous winter's temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Early winter temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Early winter temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Tree seed & berry crop		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Previous winter's temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Early winter temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Tree seed & berry crop		0.213	0.203	1.033	0.138	0.941				
Great Black-backed Gull	Previous winter's temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Early winter temperature		0.241	0.047	0.229	0.614	1.000	0.152	0.161	NA	2,749.8
Great Black-backed Gull	Tree seed & berry crop		0.213	0.203	1.033	0.138	0.941				
Great Black-backed Gull	Tree seed & berry crop		0.213	0.203	1.033	0.138	0.941				
Common Blackbird	**Intercept only (null model)**		na	na	na	na	na	na	**0.012**	NA	
Common Blackbird	Early winter temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Previous winter's temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	**Early winter temperature**		**0.104**	**0.213**	**0.477**	**0.585**	**1.000**	**0.234**	**0.852**	76.8	
Common Blackbird	Early winter temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Previous winter's temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Early winter temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Tree seed & berry crop		0.384	0.194	3.978	0.139	0.941	0.192	0.053	47.4	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Tree seed & berry crop		0.384	0.194	3.978	0.139	0.941	0.192	0.053	47.4	
Common Blackbird	Tree seed & berry crop		0.384	0.194	3.978	0.139	0.941	0.192	0.053	47.4	
Common Blackbird	**Intercept only (null model)**		na	na	na	na	na	na	**0.012**	NA	
Common Blackbird	Early winter temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Previous winter's temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Early winter temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Early winter temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Previous winter's temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Early winter temperature		0.104	0.213	0.477	0.585	1.000	0.234	0.852	76.8	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Tree seed & berry crop		0.384	0.194	3.978	0.139	0.941	0.192	0.053	47.4	
Common Blackbird	Tree seed & berry crop		0.382	0.192	3.982	0.137	0.941	0.192	0.060	73.2	
Common Blackbird	Tree seed & berry crop		0.384	0.194	3.978	0.139	0.941	0.192	0.053	47.4	
Common Blackbird	Tree seed & berry crop		0.384	0.194	3.978	0.139	0.941	0.192	0.053	47.4	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Previous winter's temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	**Early winter temperature**		**0.104**	**0.201**	**0.269**	**0.395**	**0.927**	**0.116**	**0.578**	75.1	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Tree seed & berry crop		0.038	0.207	0.183	0.669	1.000	0.861	0.151	30.6	
Fieldfare	Previous winter's temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Tree seed & berry crop		0.038	0.207	0.183	0.669	1.000	0.861	0.151	30.6	
Fieldfare	Tree seed & berry crop		0.038	0.207	0.183	0.669	1.000	0.861	0.151	30.6	
Fieldfare	Tree seed & berry crop		0.021	0.209	0.033	0.818	1.000	0.851	0.146	30.6	
Fieldfare	Previous winter's temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Tree seed & berry crop		0.038	0.207	0.183	0.669	1.000	0.861	0.151	30.6	
Fieldfare	Tree seed & berry crop		0.021	0.209	0.033	0.818	1.000	0.851	0.146	30.6	
Fieldfare	Tree seed & berry crop		0.021	0.209	0.033	0.818	1.000	0.851	0.146	30.6	
Fieldfare	**Intercept only (null model)**		na	na	na	na	na	na	**0.012**	NA	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Previous winter's temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Tree seed & berry crop		0.038	0.207	0.183	0.669	1.000	0.861	0.151	30.6	
Fieldfare	Previous winter's temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Early winter temperature		0.104	0.201	0.269	0.395	0.927	0.116	0.578	75.1	
Fieldfare	Tree seed & berry crop		0.038	0.207	0.183	0.669	1.000	0.861	0.151	30.6	
Fieldfare	Tree seed & berry crop		0.021	0.209	0.033	0.818	1.000	0.851	0.146	30.6	
Fieldfare	Tree seed & berry crop		0.021	0.209	0.033	0.818	1.000	0.851	0.146	30.6	
Fieldfare	Tree seed & berry crop		0.021	0.209	0.033	0.818	1.000	0.851	0.146	30.6	
Fieldfare	Tree seed & berry crop		0.021	0.209	0.033	0.818	1.000	0.851	0.146	30.6	
Goldcrest	Early winter temperature		0.094	0.204	0.784	0.376	0.941	0.201	0.516	76.1	
Goldcrest	Previous winter's temperature		0.094	0.204	0.784	0.376	0.941	0.201	0.516	76.1	
Goldcrest	**Early winter temperature**		**0.094**	**0.204**	**0.784**	**0.376**	**0.941**	**0.201**	**0.516**	76.1	
Goldcrest	Early winter temperature		0.094	0.204	0.784	0.376	0.941	0.201	0.516	76.1	
Goldcrest	Tree seed & berry crop		0.448	0.193	2.834	0.019	0.118	0.228	0.308	69.9	
Goldcrest	Previous winter's temperature		0.094	0.204	0.784	0.376	0.941	0.201	0.516	76.1	
Goldcrest	Early winter temperature		0.094	0.204	0.784	0.376	0.941	0.201	0.516	76.1	
Goldcrest	Tree seed & berry crop		0.448	0.193	2.834	0.019	0.118	0.228	0.308	69.9	
Goldcrest	Tree seed & berry crop		0.448	0.193	2.834	0.019	0.118	0.228	0.308	69.9	
Blue Tit	Intercept only (null model)		na	na	na	na	na	na	0.333	NA	
Blue Tit	Early winter temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Previous winter's temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Early winter temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Early winter temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Tree seed & berry crop		0.495	0.190	3.622	0.016	0.122	0.246	0.034	69.4	
Blue Tit	Previous winter's temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Early winter temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Tree seed & berry crop		0.495	0.190	3.622	0.016	0.122	0.246	0.034	69.4	
Blue Tit	Tree seed & berry crop		0.495	0.190	3.622	0.016	0.122	0.246	0.034	69.4	
Blue Tit	Tree seed & berry crop		0.494	0.191	3.607	0.016	0.122	0.241	0.034	69.7	
Blue Tit	Previous winter's temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Early winter temperature		0.011	0.274	0.002	0.964	1.000	0.333	0.344	77.3	
Blue Tit	Tree seed & berry crop		0.495	0.190	3.622

Table S3. All models of trends in PoR. Model 1 is the null model (intercept only), model 2 is the model of linear change, and model 3 is the model of quadratic change (2nd order polynomial). Due to scaling (see text) the intercepts were always 0 and are not shown. Both unadjusted (p) and false discovery rate adjusted (FDR-p) p-values are shown. AICc is Akaike's information criterion for small sample size. The best models (the simplest models inside ΔAIC of 2) are bolded and the models used for detrending variables for the annual analyses (the most complex models inside ΔAIC of 2) are in italic.

Species	Model	Predictor	B	SE	t	p	FDR-p	df	r2	AICc
Waterbirds	Null	Intecept only	–	–	–	–	–	216	–	329.343
Waterbirds	Linear	Year	0.027	0.004	7.041	<0.001	–	215	–	295.820
Waterbirds	***Quadratic***	***Year***	***2.909***	***0.412***	***7.062***	***<0.001***	**–**	***214***	**–**	***286.128***
Waterbirds	***Quadratic***	***Year^2***	***-0.620***	***0.412***	***-1.505***	***0.134***	**–**			
Terrestrial birds	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***432***	**–**	642.352
Terrestrial birds	Linear	Year	-0.0009	0.003	-0.294	0.769	–	431	–	654.032
Terrestrial birds	Quadratic	Year	-0.136	0.463	-0.293	0.769	–	430	–	645.551
Terrestrial birds	Quadratic	Year^2	-0.164	0.463	-0.354	0.724	–			
Terrestrial non-frugivores	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***264***	**–**	**55.547**
Terrestrial non-frugivores	Linear	Year	-0.001	0.002	-0.508	0.612	–	263	–	67.823
Terrestrial non-frugivores	Quadratic	Year	-0.125	0.247	-0.507	0.612	–	262	–	61.119
Terrestrial non-frugivores	Quadratic	Year^2	-0.078	0.247	-0.315	0.753	–			
Mute Swan	Null	Intecept only	–	–	–	–	–	23	–	-1.244
Mute Swan	**Linear**	**Year**	**-0.013**	**0.006**	**-2.350**	**0.028**	**0.135**	**22**	**0.194**	**-4.251**
Mute Swan	*Quadratic*	*Year*	*-0.478*	*0.202*	*-2.359*	*0.028*	*0.135*	*21*	*0.235*	*-2.975*
Mute Swan	*Quadratic*	*Year^2*	*-0.221*	*0.202*	*-1.093*	*0.286*	*0.537*			
Whooper Swan	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**18.268**
Whooper Swan	Linear	Year	-0.012	0.009	-1.344	0.192	0.432	22	0.073	18.749
Whooper Swan	*Quadratic*	*Year*	*-0.433*	*0.316*	*-1.370*	*0.185*	*0.426*	*21*	*0.146*	*19.287*
Whooper Swan	*Quadratic*	*Year^2*	*0.434*	*0.316*	*1.374*	*0.183*	*0.426*			
Mallard	Null	Intecept only	–	–	–	–	–	23	–	-47.586
Mallard	**Linear**	**Year**	**0.008**	**0.002**	**4.289**	**<0.001**	**0.003**	**22**	**0.444**	**-59.907**
Mallard	*Quadratic*	*Year*	*0.286*	*0.067*	*4.299*	*<0.001*	*0.003*	*21*	*0.471*	*-58.536*
Mallard	*Quadratic*	*Year^2*	*0.070*	*0.067*	*1.052*	*0.304*	*0.559*			
Tufted duck	Null	Intecept only	–	–	–	–	–	23	–	71.167
Tufted duck	***Linear***	***Year***	***0.105***	***0.015***	***6.920***	***<0.001***	***<0.001***	***22***	***0.676***	***45.398***
Tufted duck	Quadratic	Year	3.797	0.557	6.817	<0.001	<0.001	21	0.680	47.632
Tufted duck	Quadratic	Year^2	0.316	0.557	0.568	0.576	0.810			
Common Goldeneye	Null	Intecept only	–	–	–	–	–	23	–	43.569
Common Goldeneye	**Linear**	**Year**	**0.071**	**0.004**	**16.282**	**<0.001**	**<0.001**	**22**	**0.920**	**-17.256**
Common Goldeneye	*Quadratic*	*Year*	*2.552*	*0.158*	*16.153*	*<0.001*	*<0.001*	*21*	*0.922*	*-15.371*
Common Goldeneye	*Quadratic*	*Year^2*	*-0.126*	*0.158*	*-0.798*	*0.434*	*0.709*			
Goosander	Null	Intecept only	–	–	–	–	–	23	–	7.547
Goosander	***Linear***	***Year***	***0.028***	***0.005***	***5.850***	***<0.001***	***<0.001***	***22***	***0.598***	***-12.865***
Goosander	Quadratic	Year	1.001	0.175	5.721	<0.001	<0.001	21	0.598	-10.269
Goosander	Quadratic	Year^2	0.005	0.175	0.027	0.978	0.999			
Mew Gull	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**30.686**
Mew Gull	Linear	Year	0.007	0.012	0.553	0.586	0.810	22	0.013	32.727
Mew Gull	*Quadratic*	*Year*	*0.235*	*0.390*	*0.604*	*0.552*	*0.810*	*21*	*0.210*	*29.754*
Mew Gull	*Quadratic*	*Year^2*	*-0.913*	*0.390*	*-2.343*	*0.029*	*0.135*			
Herring Gull	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**30.771**
Herring Gull	Linear	Year	0.020	0.011	1.804	0.084	0.281	22	0.124	29.835
Herring Gull	*Quadratic*	*Year*	*0.725*	*0.387*	*1.873*	*0.074*	*0.268*	*21*	*0.223*	*29.434*
Herring Gull	*Quadratic*	*Year^2*	*-0.648*	*0.387*	*-1.674*	*0.108*	*0.326*			
Great Black-backed Gull	Null	Intecept only	–	–	–	–	–	23	–	19.079
Great Black-backed Gull	Linear	Year	0.029	0.007	3.978	0.001	0.005	22	0.408	8.362
Great Black-backed Gull	***Quadratic***	***Year***	***1.041***	***0.210***	***4.957***	***<0.001***	***0.001***	***21***	***0.635***	***-1.151***
Great Black-backed Gull	***Quadratic***	***Year^2***	***-0.777***	***0.210***	***-3.703***	***0.001***	***0.010***			
Common Blackbird	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**11.000**
Common Blackbird	*Linear*	*Year*	*0.010*	*0.008*	*1.253*	*0.223*	*0.442*	*22*	*0.064*	*11.720*
Common Blackbird	Quadratic	Year	0.351	0.286	1.227	0.233	0.446	21	0.066	14.250
Common Blackbird	Quadratic	Year^2	-0.070	0.286	-0.244	0.810	0.985			
Fieldfare	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***23***	**–**	***81.753***
Fieldfare	Linear	Year	-0.003	0.033	-0.086	0.932	0.999	22	0.000	84.117
Fieldfare	Quadratic	Year	-0.102	1.208	-0.085	0.933	0.999	21	0.015	86.353
Fieldfare	Quadratic	Year^2	-0.684	1.208	-0.566	0.577	0.810			
Goldcrest	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**-24.011**
Goldcrest	*Linear*	*Year*	*-0.005*	*0.004*	*-1.287*	*0.211*	*0.442*	*22*	*0.067*	*-23.377*
Goldcrest	Quadratic	Year	-0.178	0.142	-1.259	0.221	0.442	21	0.068	-20.813
Goldcrest	Quadratic	Year^2	-0.024	0.142	-0.170	0.866	0.987			
Blue Tit	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**-57.751**
Blue Tit	*Linear*	*Year*	*0.003*	*0.002*	*1.636*	*0.115*	*0.326*	*22*	*0.104*	*-58.131*
Blue Tit	Quadratic	Year	0.113	0.070	1.609	0.122	0.327	21	0.114	-55.808
Blue Tit	Quadratic	Year^2	0.035	0.070	0.493	0.627	0.810			
Great Tit	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**-60.373**
Great Tit	Linear	Year	-0.004	0.002	-2.024	0.055	0.224	22	0.151	-62.101
Great Tit	*Quadratic*	*Year*	*-0.129*	*0.065*	*-2.001*	*0.058*	*0.227*	*21*	*0.169*	*-60.022*
Great Tit	*Quadratic*	*Year^2*	*-0.044*	*0.065*	*-0.679*	*0.504*	*0.783*			
Eurasian Treecreeper	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**-40.656**
Eurasian Treecreeper	*Linear*	*Year*	*-0.003*	*0.003*	*-1.268*	*0.218*	*0.442*	*22*	*0.065*	*-39.972*
Eurasian Treecreeper	Quadratic	Year	-0.126	0.101	-1.246	0.226	0.442	21	0.075	-37.631
Eurasian Treecreeper	Quadratic	Year^2	-0.048	0.101	-0.476	0.639	0.810			
Jackdaw	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**-24.111**
Jackdaw	Linear	Year	-0.0002	0.004	-0.041	0.967	0.999	22	0.000	-21.742
Jackdaw	*Quadratic*	*Year*	*-0.006*	*0.129*	*-0.046*	*0.964*	*0.999*	*21*	*0.229*	*-25.659*
Jackdaw	*Quadratic*	*Year^2*	*0.329*	*0.129*	*2.559*	*0.018*	*0.101*			
Hooded Crow	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**-87.346**
Hooded Crow	*Linear*	*Year*	*0.002*	*0.001*	*1.599*	*0.124*	*0.327*	*22*	*0.100*	*-87.609*
Hooded Crow	Quadratic	Year	0.061	0.039	1.567	0.131	0.338	21	0.104	-85.126
Hooded Crow	Quadratic	Year^2	-0.012	0.039	-0.318	0.753	0.941			
Common Starling	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**44.987**
Common Starling	*Linear*	*Year*	*-0.014*	*0.016*	*-0.880*	*0.388*	*0.658*	*22*	*0.033*	*46.531*
Common Starling	Quadratic	Year	-0.494	0.567	-0.871	0.393	0.658	21	0.055	48.547
Common Starling	Quadratic	Year^2	-0.408	0.567	-0.719	0.480	0.771			
Chaffinch	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***23***	**–**	***7.777***
Chaffinch	Linear	Year	0.001	0.008	0.067	0.947	0.999	22	0.000	10.143
Chaffinch	Quadratic	Year	0.018	0.277	0.066	0.948	0.999	21	0.004	12.646
Chaffinch	Quadratic	Year^2	0.080	0.277	0.289	0.775	0.956			
Brambling	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***23***	**–**	***33.739***
Brambling	Linear	Year	-0.00001	0.013	-0.001	0.999	0.999	22	0.000	36.110
Brambling	Quadratic	Year	-0.0004	0.465	-0.001	0.999	0.999	21	0.002	38.656
Brambling	Quadratic	Year^2	-0.100	0.465	-0.215	0.832	0.987			
Greenfinch	Null	Intecept only	–	–	–	–	–	23	–	-32.979
Greenfinch	***Linear***	***Year***	***-0.009***	***0.003***	***-3.417***	***0.002***	***0.018***	***22***	***0.337***	***-40.871***
Greenfinch	Quadratic	Year	-0.334	0.099	-3.373	0.003	0.019	21	0.349	-38.736
Greenfinch	Quadratic	Year^2	0.063	0.099	0.641	0.528	0.806			
Eurasian Siskin	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**56.457**
Eurasian Siskin	*Linear*	*Year*	*0.018*	*0.020*	*0.918*	*0.368*	*0.658*	*22*	*0.035*	*57.929*
Eurasian Siskin	Quadratic	Year	0.647	0.717	0.903	0.376	0.658	21	0.046	60.262
Eurasian Siskin	Quadratic	Year^2	-0.347	0.717	-0.484	0.633	0.810			
Common Redpoll	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***23***	**–**	***37.760***
Common Redpoll	Linear	Year	-0.001	0.014	-0.056	0.955	0.999	22	0.000	40.128
Common Redpoll	Quadratic	Year	-0.028	0.505	-0.055	0.956	0.999	21	0.002	42.686
Common Redpoll	Quadratic	Year^2	0.094	0.505	0.186	0.854	0.987			
Common Crossbill	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***23***	**–**	***62.936***
Common Crossbill	Linear	Year	-0.004	0.023	-0.178	0.860	0.987	22	0.001	65.273
Common Crossbill	Quadratic	Year	-0.145	0.826	-0.176	0.862	0.987	21	0.023	67.331
Common Crossbill	Quadratic	Year^2	0.572	0.826	0.693	0.496	0.783			
Eurasian Bullfinch	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**1.310**
Eurasian Bullfinch	Linear	Year	-0.011	0.006	-1.739	0.095	0.307	22	0.116	0.592
Eurasian Bullfinch	*Quadratic*	*Year*	*-0.390*	*0.212*	*-1.836*	*0.080*	*0.276*	*21*	*0.242*	*-0.641*
Eurasian Bullfinch	*Quadratic*	*Year^2*	*0.405*	*0.212*	*1.909*	*0.069*	*0.260*			
Yellowhammer	**Null**	**Intecept only**	**–**	**–**	**–**	**–**	**–**	**23**	**–**	**-55.861**
Yellowhammer	Linear	Year	-0.003	0.002	-1.481	0.152	0.380	22	0.087	-55.767
Yellowhammer	Quadratic	Year	-0.107	0.074	-1.457	0.159	0.387	21	0.098	-53.475
Yellowhammer	Quadratic	Year^2	-0.038	0.074	-0.520	0.609	0.810			
Reed Bunting	***Null***	***Intecept only***	**–**	**–**	**–**	**–**	**–**	***23***	**–**	***45.259***
Reed Bunting	Linear	Year	0.008	0.016	0.480	0.636	0.810	22	0.010	47.382
Reed Bunting	Quadratic	Year	0.274	0.574	0.477	0.638	0.810	21	0.043	49.138
Reed Bunting	Quadratic	Year^2	-0.498	0.574	-0.868	0.395	0.658			

Table S4. All models of trends in tree crops (spruce and birch seeds, rowanberries) and winter temperatures. Every species has different temperatures because they were calculated species-specifically (see text for details). Model 1 is the null model, model 2 is the model of linear change, and model 3 is the model of quadratic change (2nd order polynomial). Due to scaling (see text) the intercepts were always 0 and are not shown. AICc is Akaike's information criterion for small sample size. The best models (the simplest models inside delta-AIC of 2) are bolded and the models used for detrending variables for the annual analyses (the most complex models inside delta-AIC of 2) are in italic.

Type	Species	Model	Predictor	B	SE	t	p	df	r2	AICc
Seed and berry crop	**Spruce**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**52.6**
Seed and berry crop	*Spruce*	*Linear*	*Year*	*-0.014*	*0.018*	*-0.772*	*0.448*	*22*	*0.025*	*54.3*
Seed and berry crop	Spruce	Quadratic	Year	-0.506	0.670	-0.755	0.458	21	0.027	56.9
Seed and berry crop	Spruce	Quadratic	Year^2	-0.114	0.670	-0.170	0.867	21	0.027	56.9
Seed and berry crop	***Birch***	***Null***	***Intecept only***	–	–	–	–	**23**	–	**14.7**
Seed and berry crop	Birch	Linear	Year	-0.002	0.009	-0.179	0.859	22	0.001	16.5
Seed and berry crop	Birch	Quadratic	Year	-0.055	0.314	-0.176	0.862	21	0.002	19.0
Seed and berry crop	Birch	Quadratic	Year^2	0.048	0.314	0.153	0.879	21	0.002	19.0
Seed and berry crop	***Rowan***	***Null***	***Intecept only***	–	–	–	–	**23**	–	**92.2**
Seed and berry crop	Rowan	Linear	Year	-0.003	0.041	-0.070	0.945	22	0.000	94.6
Seed and berry crop	Rowan	Quadratic	Year	-0.103	1.493	-0.069	0.946	21	0.011	96.9
Seed and berry crop	Rowan	Quadratic	Year^2	0.738	1.493	0.494	0.626	21	0.011	96.9
Early winter temperature	**Mute Swan**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**113.6**
Early winter temperature	Mute Swan	Linear	Year	0.057	0.061	0.925	0.365	22	0.036	115.1
Early winter temperature	Mute Swan	Quadratic	Year	2.045	2.236	0.915	0.370	21	0.058	117.1
Early winter temperature	Mute Swan	Quadratic	Year^2	-1.596	2.236	-0.714	0.483	21	0.058	117.1
Early winter temperature	**Whooper Swan**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**119.2**
Early winter temperature	*Whooper Swan*	*Linear*	*Year*	*0.075*	*0.068*	*1.108*	*0.279*	*22*	*0.051*	*120.3*
Early winter temperature	Whooper Swan	Quadratic	Year	2.718	2.479	1.097	0.285	21	0.073	122.3
Early winter temperature	Whooper Swan	Quadratic	Year^2	-1.808	2.479	-0.730	0.473	21	0.073	122.3
Early winter temperature	**Mallard**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**119.2**
Early winter temperature	*Mallard*	*Linear*	*Year*	*0.075*	*0.068*	*1.111*	*0.278*	*22*	*0.051*	*120.2*
Early winter temperature	Mallard	Quadratic	Year	2.722	2.476	1.099	0.284	21	0.073	122.2
Early winter temperature	Mallard	Quadratic	Year^2	-1.800	2.476	-0.727	0.475	21	0.073	122.2
Early winter temperature	**Tufted duck**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**116.6**
Early winter temperature	*Tufted duck*	*Linear*	*Year*	*0.069*	*0.065*	*1.067*	*0.297*	*22*	*0.047*	*117.8*
Early winter temperature	Tufted duck	Quadratic	Year	2.490	2.359	1.056	0.303	21	0.068	119.8
Early winter temperature	Tufted duck	Quadratic	Year^2	-1.670	2.359	-0.708	0.486	21	0.068	119.8
Early winter temperature	**Common Goldeneye**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**118.4**
Early winter temperature	*Common Goldeneye*	*Linear*	*Year*	*0.075*	*0.067*	*1.113*	*0.277*	*22*	*0.051*	*119.5*
Early winter temperature	Common Goldeneye	Quadratic	Year	2.689	2.442	1.101	0.283	21	0.072	121.5
Early winter temperature	Common Goldeneye	Quadratic	Year^2	-1.731	2.442	-0.709	0.486	21	0.072	121.5
Early winter temperature	**Goosander**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**118.3**
Early winter temperature	*Goosander*	*Linear*	*Year*	*0.074*	*0.067*	*1.100*	*0.283*	*22*	*0.050*	*119.4*
Early winter temperature	Goosander	Quadratic	Year	2.652	2.437	1.088	0.288	21	0.071	121.4
Early winter temperature	Goosander	Quadratic	Year^2	-1.738	2.437	-0.713	0.483	21	0.071	121.4
Early winter temperature	**Mew Gull**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**118.1**
Early winter temperature	*Mew Gull*	*Linear*	*Year*	*0.071*	*0.067*	*1.072*	*0.295*	*22*	*0.048*	*119.3*
Early winter temperature	Mew Gull	Quadratic	Year	2.578	2.430	1.061	0.300	21	0.069	121.3
Early winter temperature	Mew Gull	Quadratic	Year^2	-1.739	2.430	-0.716	0.482	21	0.069	121.3
Early winter temperature	**Herring Gull**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**118.3**
Early winter temperature	*Herring Gull*	*Linear*	*Year*	*0.072*	*0.067*	*1.082*	*0.291*	*22*	*0.048*	*119.4*
Early winter temperature	Herring Gull	Quadratic	Year	2.608	2.437	1.070	0.296	21	0.070	121.4
Early winter temperature	Herring Gull	Quadratic	Year^2	-1.742	2.437	-0.715	0.482	21	0.070	121.4
Early winter temperature	**Great Black-backed Gull**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**114.0**
Early winter temperature	*Great Black-backed Gull*	*Linear*	*Year*	*0.061*	*0.062*	*0.986*	*0.334*	*22*	*0.041*	*115.3*
Early winter temperature	Great Black-backed Gull	Quadratic	Year	2.192	2.248	0.975	0.340	21	0.061	117.4
Early winter temperature	Great Black-backed Gull	Quadratic	Year^2	-1.557	2.248	-0.692	0.496	21	0.061	117.4
Early winter temperature	**Common Blackbird**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**118.7**
Early winter temperature	*Common Blackbird*	*Linear*	*Year*	*0.072*	*0.067*	*1.068*	*0.297*	*22*	*0.047*	*119.8*
Early winter temperature	Common Blackbird	Quadratic	Year	2.597	2.458	1.057	0.302	21	0.069	121.9
Early winter temperature	Common Blackbird	Quadratic	Year^2	-1.769	2.458	-0.720	0.479	21	0.069	121.9
Early winter temperature	**Fieldfare**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**119.9**
Early winter temperature	*Fieldfare*	*Linear*	*Year*	*0.079*	*0.069*	*1.143*	*0.265*	*22*	*0.054*	*120.9*
Early winter temperature	Fieldfare	Quadratic	Year	2.839	2.511	1.131	0.270	21	0.076	122.9
Early winter temperature	Fieldfare	Quadratic	Year^2	-1.821	2.511	-0.725	0.476	21	0.076	122.9
Early winter temperature	**Goldcrest**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.2**
Early winter temperature	*Goldcrest*	*Linear*	*Year*	*0.079*	*0.069*	*1.132*	*0.269*	*22*	*0.053*	*121.2*
Early winter temperature	Goldcrest	Quadratic	Year	2.831	2.527	1.120	0.275	21	0.075	123.2
Early winter temperature	Goldcrest	Quadratic	Year^2	-1.848	2.527	-0.732	0.472	21	0.075	123.2
Early winter temperature	**Blue Tit**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**119.9**
Early winter temperature	*Blue Tit*	*Linear*	*Year*	*0.079*	*0.069*	*1.146*	*0.264*	*22*	*0.054*	*120.9*
Early winter temperature	Blue Tit	Quadratic	Year	2.844	2.508	1.134	0.269	21	0.076	122.9
Early winter temperature	Blue Tit	Quadratic	Year^2	-1.826	2.508	-0.728	0.474	21	0.076	122.9
Early winter temperature	**Great Tit**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.5**
Early winter temperature	*Great Tit*	*Linear*	*Year*	*0.084*	*0.069*	*1.212*	*0.238*	*22*	*0.060*	*121.3*
Early winter temperature	Great Tit	Quadratic	Year	3.036	2.531	1.200	0.243	21	0.082	123.3
Early winter temperature	Great Tit	Quadratic	Year^2	-1.829	2.531	-0.723	0.478	21	0.082	123.3
Early winter temperature	**Eurasian Treecreeper**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.3**
Early winter temperature	*Eurasian Treecreeper*	*Linear*	*Year*	*0.080*	*0.069*	*1.146*	*0.264*	*22*	*0.054*	*121.3*
Early winter temperature	Eurasian Treecreeper	Quadratic	Year	2.868	2.529	1.134	0.269	21	0.076	123.3
Early winter temperature	Eurasian Treecreeper	Quadratic	Year^2	-1.844	2.529	-0.729	0.474	21	0.076	123.3
Early winter temperature	**Jackdaw**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**118.8**
Early winter temperature	*Jackdaw*	*Linear*	*Year*	*0.072*	*0.068*	*1.065*	*0.298*	*22*	*0.047*	*119.9*
Early winter temperature	Jackdaw	Quadratic	Year	2.594	2.461	1.054	0.303	21	0.070	121.9
Early winter temperature	Jackdaw	Quadratic	Year^2	-1.803	2.461	-0.732	0.472	21	0.070	121.9
Early winter temperature	**Hooded Crow**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.2**
Early winter temperature	*Hooded Crow*	*Linear*	*Year*	*0.081*	*0.069*	*1.176*	*0.251*	*22*	*0.057*	*121.1*
Early winter temperature	Hooded Crow	Quadratic	Year	2.935	2.521	1.164	0.257	21	0.079	123.1
Early winter temperature	Hooded Crow	Quadratic	Year^2	-1.829	2.521	-0.726	0.476	21	0.079	123.1
Early winter temperature	**Common Starling**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**116.7**
Early winter temperature	*Common Starling*	*Linear*	*Year*	*0.068*	*0.065*	*1.047*	*0.306*	*22*	*0.045*	*117.9*
Early winter temperature	Common Starling	Quadratic	Year	2.450	2.365	1.036	0.312	21	0.068	119.9
Early winter temperature	Common Starling	Quadratic	Year^2	-1.706	2.365	-0.721	0.478	21	0.068	119.9
Early winter temperature	**Chaffinch**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**117.8**
Early winter temperature	*Chaffinch*	*Linear*	*Year*	*0.072*	*0.066*	*1.090*	*0.287*	*22*	*0.049*	*118.9*
Early winter temperature	Chaffinch	Quadratic	Year	2.602	2.413	1.079	0.292	21	0.070	120.9
Early winter temperature	Chaffinch	Quadratic	Year^2	-1.706	2.413	-0.707	0.487	21	0.070	120.9
Early winter temperature	**Brambling**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**116.7**
Early winter temperature	*Brambling*	*Linear*	*Year*	*0.068*	*0.065*	*1.049*	*0.305*	*22*	*0.046*	*117.9*
Early winter temperature	Brambling	Quadratic	Year	2.456	2.368	1.037	0.311	21	0.066	120.0
Early winter temperature	Brambling	Quadratic	Year^2	-1.624	2.368	-0.686	0.500	21	0.066	120.0
Early winter temperature	**Greenfinch**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**119.8**
Early winter temperature	*Greenfinch*	*Linear*	*Year*	*0.079*	*0.069*	*1.145*	*0.264*	*22*	*0.054*	*120.7*
Early winter temperature	Greenfinch	Quadratic	Year	2.836	2.502	1.134	0.269	21	0.076	122.7
Early winter temperature	Greenfinch	Quadratic	Year^2	-1.817	2.502	-0.726	0.475	21	0.076	122.7
Early winter temperature	**Eurasian Siskin**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**119.5**
Early winter temperature	*Eurasian Siskin*	*Linear*	*Year*	*0.075*	*0.068*	*1.101*	*0.282*	*22*	*0.050*	*120.6*
Early winter temperature	Eurasian Siskin	Quadratic	Year	2.718	2.495	1.089	0.288	21	0.073	122.6
Early winter temperature	Eurasian Siskin	Quadratic	Year^2	-1.822	2.495	-0.730	0.473	21	0.073	122.6
Early winter temperature	**Common Redpoll**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.5**
Early winter temperature	*Common Redpoll*	*Linear*	*Year*	*0.084*	*0.070*	*1.204*	*0.241*	*22*	*0.059*	*121.3*
Early winter temperature	Common Redpoll	Quadratic	Year	3.018	2.533	1.192	0.246	21	0.081	123.4
Early winter temperature	Common Redpoll	Quadratic	Year^2	-1.830	2.533	-0.723	0.478	21	0.081	123.4
Early winter temperature	**Common Crossbill**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.4**
Early winter temperature	*Common Crossbill*	*Linear*	*Year*	*0.082*	*0.069*	*1.189*	*0.247*	*22*	*0.058*	*121.3*
Early winter temperature	Common Crossbill	Quadratic	Year	2.974	2.529	1.176	0.252	21	0.079	123.3
Early winter temperature	Common Crossbill	Quadratic	Year^2	-1.815	2.529	-0.718	0.481	21	0.079	123.3
Early winter temperature	**Eurasian Bullfinch**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.4**
Early winter temperature	*Eurasian Bullfinch*	*Linear*	*Year*	*0.083*	*0.069*	*1.196*	*0.244*	*22*	*0.059*	*121.3*
Early winter temperature	Eurasian Bullfinch	Quadratic	Year	2.996	2.531	1.184	0.249	21	0.080	123.3
Early winter temperature	Eurasian Bullfinch	Quadratic	Year^2	-1.827	2.531	-0.722	0.478	21	0.080	123.3
Early winter temperature	**Yellowhammer**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**120.4**
Early winter temperature	*Yellowhammer*	*Linear*	*Year*	*0.080*	*0.070*	*1.153*	*0.261*	*22*	*0.055*	*121.3*
Early winter temperature	Yellowhammer	Quadratic	Year	2.890	2.532	1.141	0.266	21	0.077	123.3
Early winter temperature	Yellowhammer	Quadratic	Year^2	-1.844	2.532	-0.728	0.474	21	0.077	123.3
Early winter temperature	**Reed Bunting**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**112.7**
Early winter temperature	*Reed Bunting*	*Linear*	*Year*	*0.056*	*0.060*	*0.935*	*0.359*	*22*	*0.037*	*114.2*
Early winter temperature	Reed Bunting	Quadratic	Year	2.030	2.195	0.925	0.365	21	0.058	116.2
Early winter temperature	Reed Bunting	Quadratic	Year^2	-1.552	2.195	-0.707	0.487	21	0.058	116.2
Previous winter's temperature	**Mute Swan**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**124.2**
Previous winter's temperature	Mute Swan	Linear	Year	0.068	0.076	0.899	0.378	22	0.034	125.7
Previous winter's temperature	*Mute Swan*	*Quadratic*	*Year*	*2.461*	*2.679*	*0.918*	*0.368*	*21*	*0.114*	*126.2*
Previous winter's temperature	*Mute Swan*	*Quadratic*	*Year^2*	*-3.772*	*2.679*	*-1.408*	*0.173*	*21*	*0.114*	*126.2*
Previous winter's temperature	**Whooper Swan**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.2**
Previous winter's temperature	Whooper Swan	Linear	Year	0.074	0.081	0.924	0.365	22	0.036	128.7
Previous winter's temperature	*Whooper Swan*	*Quadratic*	*Year*	*2.682*	*2.841*	*0.944*	*0.355*	*21*	*0.117*	*129.1*
Previous winter's temperature	*Whooper Swan*	*Quadratic*	*Year^2*	*-4.042*	*2.841*	*-1.423*	*0.169*	*21*	*0.117*	*129.1*
Previous winter's temperature	**Mallard**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.2**
Previous winter's temperature	Mallard	Linear	Year	0.073	0.081	0.906	0.374	22	0.034	128.7
Previous winter's temperature	*Mallard*	*Quadratic*	*Year*	*2.632*	*2.843*	*0.926*	*0.365*	*21*	*0.115*	*129.1*
Previous winter's temperature	*Mallard*	*Quadratic*	*Year^2*	*-4.019*	*2.843*	*-1.414*	*0.171*	*21*	*0.115*	*129.1*
Previous winter's temperature	**Tufted duck**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**125.9**
Previous winter's temperature	Tufted duck	Linear	Year	0.072	0.078	0.921	0.366	22	0.036	127.4
Previous winter's temperature	*Tufted duck*	*Quadratic*	*Year*	*2.605*	*2.769*	*0.941*	*0.357*	*21*	*0.115*	*127.8*
Previous winter's temperature	*Tufted duck*	*Quadratic*	*Year^2*	*-3.896*	*2.769*	*-1.407*	*0.173*	*21*	*0.115*	*127.8*
Previous winter's temperature	**Common Goldeneye**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**126.7**
Previous winter's temperature	Common Goldeneye	Linear	Year	0.072	0.080	0.908	0.373	22	0.035	128.2
Previous winter's temperature	*Common Goldeneye*	*Quadratic*	*Year*	*2.609*	*2.814*	*0.927*	*0.364*	*21*	*0.114*	*128.6*
Previous winter's temperature	*Common Goldeneye*	*Quadratic*	*Year^2*	*-3.943*	*2.814*	*-1.401*	*0.175*	*21*	*0.114*	*128.6*
Previous winter's temperature	**Goosander**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**126.6**
Previous winter's temperature	Goosander	Linear	Year	0.072	0.080	0.905	0.375	22	0.034	128.1
Previous winter's temperature	*Goosander*	*Quadratic*	*Year*	*2.594*	*2.810*	*0.923*	*0.366*	*21*	*0.114*	*128.5*
Previous winter's temperature	*Goosander*	*Quadratic*	*Year^2*	*-3.943*	*2.810*	*-1.404*	*0.174*	*21*	*0.114*	*128.5*
Previous winter's temperature	**Mew Gull**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**126.8**
Previous winter's temperature	Mew Gull	Linear	Year	0.071	0.080	0.883	0.386	22	0.033	128.3
Previous winter's temperature	*Mew Gull*	*Quadratic*	*Year*	*2.547*	*2.824*	*0.902*	*0.377*	*21*	*0.113*	*128.8*
Previous winter's temperature	*Mew Gull*	*Quadratic*	*Year^2*	*-3.969*	*2.824*	*-1.405*	*0.174*	*21*	*0.113*	*128.8*
Previous winter's temperature	**Herring Gull**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**126.8**
Previous winter's temperature	Herring Gull	Linear	Year	0.072	0.080	0.899	0.378	22	0.034	128.3
Previous winter's temperature	*Herring Gull*	*Quadratic*	*Year*	*2.591*	*2.822*	*0.918*	*0.369*	*21*	*0.114*	*128.8*
Previous winter's temperature	*Herring Gull*	*Quadratic*	*Year^2*	*-3.981*	*2.822*	*-1.411*	*0.172*	*21*	*0.114*	*128.8*
Previous winter's temperature	**Great Black-backed Gull**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**124.5**
Previous winter's temperature	Great Black-backed Gull	Linear	Year	0.071	0.076	0.932	0.361	22	0.036	125.9
Previous winter's temperature	*Great Black-backed Gull*	*Quadratic*	*Year*	*2.560*	*2.689*	*0.952*	*0.351*	*21*	*0.116*	*126.4*
Previous winter's temperature	*Great Black-backed Gull*	*Quadratic*	*Year^2*	*-3.784*	*2.689*	*-1.407*	*0.173*	*21*	*0.116*	*126.4*
Previous winter's temperature	**Common Blackbird**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.1**
Previous winter's temperature	*Common Blackbird*	*Linear*	*Year*	*0.070*	*0.080*	*0.873*	*0.392*	*22*	*0.032*	*128.6*
Previous winter's temperature	Common Blackbird	Quadratic	Year	2.530	2.840	0.891	0.383	21	0.111	129.1
Previous winter's temperature	Common Blackbird	Quadratic	Year^2	-3.982	2.840	-1.402	0.175	21	0.111	129.1
Previous winter's temperature	**Fieldfare**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Fieldfare	Linear	Year	0.075	0.081	0.932	0.361	22	0.036	128.9
Previous winter's temperature	*Fieldfare*	*Quadratic*	*Year*	*2.717*	*2.854*	*0.952*	*0.351*	*21*	*0.117*	*129.3*
Previous winter's temperature	*Fieldfare*	*Quadratic*	*Year^2*	*-4.056*	*2.854*	*-1.421*	*0.169*	*21*	*0.117*	*129.3*
Previous winter's temperature	**Goldcrest**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.8**
Previous winter's temperature	Goldcrest	Linear	Year	0.074	0.081	0.907	0.374	22	0.035	129.3
Previous winter's temperature	*Goldcrest*	*Quadratic*	*Year*	*2.663*	*2.874*	*0.926*	*0.364*	*21*	*0.115*	*129.7*
Previous winter's temperature	*Goldcrest*	*Quadratic*	*Year^2*	*-4.068*	*2.874*	*-1.415*	*0.171*	*21*	*0.115*	*129.7*
Previous winter's temperature	**Blue Tit**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Blue Tit	Linear	Year	0.075	0.081	0.926	0.364	22	0.036	128.9
Previous winter's temperature	*Blue Tit*	*Quadratic*	*Year*	*2.702*	*2.854*	*0.947*	*0.354*	*21*	*0.117*	*129.3*
Previous winter's temperature	*Blue Tit*	*Quadratic*	*Year^2*	*-4.056*	*2.854*	*-1.421*	*0.169*	*21*	*0.117*	*129.3*
Previous winter's temperature	**Great Tit**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Great Tit	Linear	Year	0.079	0.081	0.974	0.340	22	0.040	128.8
Previous winter's temperature	*Great Tit*	*Quadratic*	*Year*	*2.836*	*2.847*	*0.996*	*0.330*	*21*	*0.122*	*129.2*
Previous winter's temperature	*Great Tit*	*Quadratic*	*Year^2*	*-4.076*	*2.847*	*-1.432*	*0.166*	*21*	*0.122*	*129.2*
Previous winter's temperature	**Eurasian Treecreeper**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.8**
Previous winter's temperature	Eurasian Treecreeper	Linear	Year	0.074	0.081	0.915	0.370	22	0.035	129.2
Previous winter's temperature	*Eurasian Treecreeper*	*Quadratic*	*Year*	*2.686*	*2.873*	*0.935*	*0.360*	*21*	*0.116*	*129.7*
Previous winter's temperature	*Eurasian Treecreeper*	*Quadratic*	*Year^2*	*-4.068*	*2.873*	*-1.416*	*0.171*	*21*	*0.116*	*129.7*
Previous winter's temperature	**Jackdaw**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.3**
Previous winter's temperature	Jackdaw	Linear	Year	0.072	0.081	0.891	0.382	22	0.033	128.8
Previous winter's temperature	*Jackdaw*	*Quadratic*	*Year*	*2.593*	*2.848*	*0.910*	*0.372*	*21*	*0.114*	*129.2*
Previous winter's temperature	*Jackdaw*	*Quadratic*	*Year^2*	*-4.038*	*2.848*	*-1.418*	*0.170*	*21*	*0.114*	*129.2*
Previous winter's temperature	**Hooded Crow**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Hooded Crow	Linear	Year	0.077	0.081	0.952	0.351	22	0.038	128.9
Previous winter's temperature	*Hooded Crow*	*Quadratic*	*Year*	*2.775*	*2.852*	*0.973*	*0.341*	*21*	*0.119*	*129.3*
Previous winter's temperature	*Hooded Crow*	*Quadratic*	*Year^2*	*-4.070*	*2.852*	*-1.427*	*0.168*	*21*	*0.119*	*129.3*
Previous winter's temperature	**Common Starling**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**125.8**
Previous winter's temperature	Common Starling	Linear	Year	0.069	0.078	0.886	0.385	22	0.033	127.3
Previous winter's temperature	*Common Starling*	*Quadratic*	*Year*	*2.504*	*2.767*	*0.905*	*0.375*	*21*	*0.113*	*127.8*
Previous winter's temperature	*Common Starling*	*Quadratic*	*Year^2*	*-3.905*	*2.767*	*-1.411*	*0.172*	*21*	*0.113*	*127.8*
Previous winter's temperature	**Chaffinch**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**126.4**
Previous winter's temperature	*Chaffinch*	*Linear*	*Year*	*0.070*	*0.079*	*0.886*	*0.385*	*22*	*0.033*	*127.9*
Previous winter's temperature	Chaffinch	Quadratic	Year	2.530	2.799	0.904	0.376	21	0.112	128.4
Previous winter's temperature	Chaffinch	Quadratic	Year^2	-3.912	2.799	-1.398	0.176	21	0.112	128.4
Previous winter's temperature	**Brambling**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**125.7**
Previous winter's temperature	*Brambling*	*Linear*	*Year*	*0.068*	*0.078*	*0.864*	*0.396*	*22*	*0.031*	*127.3*
Previous winter's temperature	Brambling	Quadratic	Year	2.439	2.767	0.882	0.388	21	0.110	127.8
Previous winter's temperature	Brambling	Quadratic	Year^2	-3.848	2.767	-1.391	0.178	21	0.110	127.8
Previous winter's temperature	**Greenfinch**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.4**
Previous winter's temperature	Greenfinch	Linear	Year	0.075	0.081	0.935	0.360	22	0.037	128.8
Previous winter's temperature	*Greenfinch*	*Quadratic*	*Year*	*2.721*	*2.848*	*0.955*	*0.350*	*21*	*0.118*	*129.2*
Previous winter's temperature	*Greenfinch*	*Quadratic*	*Year^2*	*-4.054*	*2.848*	*-1.423*	*0.169*	*21*	*0.118*	*129.2*
Previous winter's temperature	**Eurasian Siskin**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Eurasian Siskin	Linear	Year	0.072	0.081	0.892	0.382	22	0.033	129.1
Previous winter's temperature	*Eurasian Siskin*	*Quadratic*	*Year*	*2.608*	*2.863*	*0.911*	*0.372*	*21*	*0.114*	*129.5*
Previous winter's temperature	*Eurasian Siskin*	*Quadratic*	*Year^2*	*-4.040*	*2.863*	*-1.411*	*0.172*	*21*	*0.114*	*129.5*
Previous winter's temperature	**Common Redpoll**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Common Redpoll	Linear	Year	0.078	0.081	0.969	0.343	22	0.039	128.9
Previous winter's temperature	*Common Redpoll*	*Quadratic*	*Year*	*2.825*	*2.851*	*0.991*	*0.333*	*21*	*0.121*	*129.3*
Previous winter's temperature	*Common Redpoll*	*Quadratic*	*Year^2*	*-4.077*	*2.851*	*-1.430*	*0.167*	*21*	*0.121*	*129.3*
Previous winter's temperature	**Common Crossbill**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Common Crossbill	Linear	Year	0.078	0.081	0.959	0.347	22	0.038	128.9
Previous winter's temperature	*Common Crossbill*	*Quadratic*	*Year*	*2.798*	*2.854*	*0.981*	*0.337*	*21*	*0.120*	*129.3*
Previous winter's temperature	*Common Crossbill*	*Quadratic*	*Year^2*	*-4.066*	*2.854*	*-1.425*	*0.168*	*21*	*0.120*	*129.3*
Previous winter's temperature	**Eurasian Bullfinch**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.5**
Previous winter's temperature	Eurasian Bullfinch	Linear	Year	0.078	0.081	0.961	0.346	22	0.039	128.9
Previous winter's temperature	*Eurasian Bullfinch*	*Quadratic*	*Year*	*2.804*	*2.853*	*0.983*	*0.336*	*21*	*0.120*	*129.3*
Previous winter's temperature	*Eurasian Bullfinch*	*Quadratic*	*Year^2*	*-4.073*	*2.853*	*-1.428*	*0.167*	*21*	*0.120*	*129.3*
Previous winter's temperature	**Yellowhammer**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**127.7**
Previous winter's temperature	Yellowhammer	Linear	Year	0.075	0.081	0.928	0.363	22	0.036	129.2
Previous winter's temperature	*Yellowhammer*	*Quadratic*	*Year*	*2.722*	*2.869*	*0.949*	*0.353*	*21*	*0.117*	*129.6*
Previous winter's temperature	*Yellowhammer*	*Quadratic*	*Year^2*	*-4.084*	*2.869*	*-1.423*	*0.169*	*21*	*0.117*	*129.6*
Previous winter's temperature	**Reed Bunting**	**Null**	**Intecept only**	–	–	–	–	**23**	–	**123.6**
Previous winter's temperature	Reed Bunting	Linear	Year	0.068	0.075	0.902	0.376	22	0.034	125.1
Previous winter's temperature	*Reed Bunting*	*Quadratic*	*Year*	*2.439*	*2.648*	*0.921*	*0.367*	*21*	*0.113*	*125.6*
Previous winter's temperature	*Reed Bunting*	*Quadratic*	*Year^2*	*-3.707*	*2.648*	*-1.400*	*0.176*	*21*	*0.113*	*125.6*

Table S5. Linear trends in components of PoR, winter abundance and summer abundance, in 30 partially migratory bird species, and in waterbirds (W), all terrestrial birds (T) and terrestrial non-frugivorous birds (T nf) as groups. Due to scaling (see text) the intercepts were always 0 and are not shown. Both unadjusted (p) and false discovery rate adjusted (FDR-p) p-values are shown.

		Winter			Summer		
Species	Group	b ± SE	p	FDR-p	b ± SE	p	FDR-p
Waterbirds	W	0.040 ± 0.005	<0.001	—	0.007 ± 0.002	<0.001	—
Terrestrial birds (all)	T	0.003 ± 0.003	0.276	—	0.004 ± 0.001	<0.001	—
Terrestrial birds (non-fr)	T nf	0.005 ± 0.002	0.023	—	0.006 ± 0.001	<0.001	—
Mute Swan	W	0.039 ± 0.013	0.006	0.016	0.030 ± 0.005	<0.001	<0.001
Whooper Swan	W	0.037 ± 0.008	<0.001	0.001	0.049 ± 0.004	<0.001	<0.001
Mallard	W	0.012 ± 0.002	<0.001	<0.001	0.004 ± 0.001	0.002	0.004
Tufted duck	W	0.093 ± 0.016	<0.001	<0.001	-0.013 ± 0.002	<0.001	<0.001
Common Goldeneye	W	0.072 ± 0.004	<0.001	<0.001	0.001 ± 0.002	0.442	0.492
Goosander	W	0.020 ± 0.005	0.001	0.004	-0.008 ± 0.002	0.001	0.003
Mew Gull	W	0.027 ± 0.027	0.324	0.405	0.005 ± 0.001	<0.001	<0.001
Herring Gull	W	0.042 ± 0.025	0.110	0.165	-0.002 ± 0.001	0.042	0.060
Great Black-backed Gull	W	0.023 ± 0.008	0.007	0.017	-0.006 ± 0.001	<0.001	<0.001
Common Blackbird	T	0.031 ± 0.008	<0.001	0.001	0.021 ± 0.001	<0.001	<0.001
Fieldfare	T	0.005 ± 0.033	0.891	0.954	0.007 ± 0.002	0.002	0.004
Goldcrest	T nf	-0.011 ± 0.005	0.024	0.049	-0.006 ± 0.004	0.122	0.155
Blue Tit	T nf	0.030 ± 0.003	<0.001	<0.001	0.026 ± 0.003	<0.001	<0.001
Great Tit	T nf	0.007 ± 0.001	<0.001	<0.001	0.010 ± 0.001	<0.001	<0.001
Eurasian Treecreeper	T nf	0.003 ± 0.003	0.320	0.405	0.007 ± 0.003	0.038	0.057
Jackdaw	T nf	0.024 ± 0.003	<0.001	<0.001	0.024 ± 0.002	<0.001	<0.001
Hooded Crow	T nf	-0.003 ± 0.001	0.030	0.053	-0.005 ± 0.001	0.001	0.001
Common Starling	T	-0.022 ± 0.015	0.145	0.207	-0.009 ± 0.002	<0.001	0.001
Chaffinch	T	0.001 ± 0.007	0.928	0.960	0.0002 ± 0.0006	0.797	0.825
Brambling	T nf	-0.008 ± 0.013	0.564	0.650	-0.008 ± 0.002	0.002	0.004
Greenfinch	T nf	0.019 ± 0.003	<0.001	<0.001	0.028 ± 0.003	<0.001	<0.001
Eurasian Siskin	T	0.022 ± 0.019	0.267	0.364	0.004 ± 0.002	0.100	0.137
Common Redpoll	T	-0.004 ± 0.012	0.723	0.804	-0.004 ± 0.004	0.429	0.492
Common Crossbill	T	-0.016 ± 0.022	0.467	0.561	-0.012 ± 0.008	0.131	0.158
Eurasian Bullfinch	T	-0.012 ± 0.005	0.038	0.063	-0.001 ± 0.005	0.859	0.859
Yellowhammer	T nf	-0.005 ± 0.002	0.010	0.021	-0.002 ± 0.001	0.124	0.155
Reed Bunting	T nf	0.00007 ± 0.016	0.996	0.996	-0.008 ± 0.002	<0.001	<0.001